Engineering Library

ENGINEERING

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Specification and Workmanship equal to Main Line Locomotives.
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See Advertisement page 99, March 7.

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See their Illus. Advertisement, page 141, last week.

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See page 121. 7263

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See Advertisement page 131. 7268

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6877
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See Full Page Advt., page 78, March 7.

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See Full Page Advertisement March 7.

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See half-page Advertisement next week.

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7006
See half-page Advertisement page 104, Feb. 21.

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For the Prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
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Heriot-Watt College, EDINBURGH.
Principal—A. P. LAURIE, M.A., D.Sc.
SPECIAL FIRST, SECOND and THIRD YEAR INTENSIVE COURSES for students demobilised from the Forces will commence on 16th April next and continue until 25th July, in the subjects of:—
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ELECTRICAL ENGINEERING.
MINING ENGINEERING.
These Courses will be suitable for Students desiring to refresh their knowledge, or who wish to qualify for the Diploma of the College, and will count as equivalent to one year of the usual Three Years Course for the Diploma, either in the First, Second or Third Years.
Fee, £12 12s. Matriculation Fee, 5s.
APPLIED CHEMISTRY.
Similar Courses in Applied Chemistry can also be obtained.
The attention of demobilised Students is directed to the arrangements made by the Government for payment of fees and maintenance of approved applicants.
Students desiring to enrol must apply, stating full particulars as to their pre-war University or Technical College Training to the Interim Principal. S 931

TENDERS.

SOUTH INDIAN RAILWAY COMPANY, LIMITED.

Tenders for Broad Gauge AND METRE GAUGE BRIDGEWORK.
The TIME for submission of Tenders has been EXTENDED, and Tenders will be received up to Eleven a.m. on WEDNESDAY, the 26th MARCH, 1919.
Finsbury Pavement House,
London, E.C. 2.
7th March, 1919. T 353

SHOEBURYNESS URBAN DISTRICT COUNCIL.

The Council have for Disposal TWO "Crossleys" (35 B.HP. maximum) GAS ENGINES, Bunsen Ignition, in excellent condition. Can be seen running at the Council's Waterworks, Shoeburyness.
Tenders to be sent to me by Four o'clock, on Tuesday, 1st April.
The Council do not bind themselves to accept the highest or any Tender.
FREDERIC GREGSON,
Southend-on-Sea, Clerk.
8th March, 1919. T 347

For Sale, Six New 25 H.P. 3-phase Squirrel Cage MOTORS, suitable for 440 volts, 50 periods at 975 r.p.m., together with Slide Rails and suitable Control Panels. The Panels are fitted with Ammeter, 3-pole Oil Switch and oil immersed Auto Transformer Starter.
The whole of the above are manufactured by Messrs. J. H. Holmes & Co., Newcastle-on-Tyne.
The highest or any Tender not necessarily accepted. Can be seen on application.—Address, T 177, Offices of ENGINEERING.

For Sale, Two sets Three-throw, horizontal type, HYDRAULIC PUMPS, 2½ in. by 12 in., for a working pressure of 1500 lbs. per square inch, driven through flexible coupling and double helicoid steel gearing by 100 B.H.P. slip-ring 3-phase Motor, 346 volts, 50 periods. Pump shaft speed about 50 r.m.p. Also AUTOMATIC SWITCH GEAR for the above motors, consisting of Automatic Controller, Resistances and Tappet Switch for working off the Accumulator.
One self-contained ACCUMULATOR, 20 in. ram by 20 ft. stroke, with 3 Centre Guide Pillar, for a working pressure of 1500 lbs. per square inch. No ballast included.
The highest or any Tender not necessarily accepted. Can be seen on application.
Address, T 178, Offices of ENGINEERING.

APPOINTMENTS OPEN.

Lecturer on Engineering WANTED, with honours degree; teaching and works experience.—State salary required and full particulars to TECHNICAL DIRECTOR, Austin Engineering College, Longbridge, Northfield, Birmingham. T 326

COUNTY BOROUGH OF BRIGHTON.
PRINCIPAL OF THE MUNICIPAL TECHNICAL COLLEGE.
The Education Committee invite
Applications for the Post of PRINCIPAL of the Municipal Technical College.
Candidates must be not more than 45 years of age and must be graduates of some University of the United Kingdom.
Salary scale £700 to £850.
Further information, and an official form on which applications must be made, may be obtained from the undersigned. Applications must be returned not later than the first post on 3rd April, 1919. T 218
F. HERBERT TOYNE,
54, Old Steine, Brighton. Secretary.

TECHNICAL INSTITUTE, WALTHAMSTOW.
ENGINEERING AND TRADE SCHOOL.
Head Master:—JAMES G. B. EDWARDS, A.M.I.M.E.
The Governors require the
Services of a Teacher of PRACTICAL MATHEMATICS, Machine Drawing and Mechanical Laboratory work. Commencing salary £200 per annum. Application forms which should be returned by March 21st, may be obtained from R. DEMPSEY, Clerk to the Governors, 1, Selborne Road, Walthamstow, E. 17. T 235

COUNTY BOROUGH OF HUDDERSFIELD TECHNICAL COLLEGE.
PRINCIPAL—J. F. HUDSON, M.A., B.Sc.
Applications are Invited for the POSITION of LECTURER in Mechanical Engineering. Commencing salary £300.
Further particulars on application to—
T. THORP, Secretary.
T 339

BATTERSEA POLYTECHNIC, LONDON, S.W.11.
The Governing Body invite
Applications for the Position of PRINCIPAL of the Polytechnic. The commencing salary of this appointment will range from £800 to £1000 a year according to qualifications, and will rise by annual increments of £20 to a maximum of £1000 a year. The appointment will date from September 1st next.
Applications must be received on or before Saturday, April 5th next.
For particulars, apply at once to the CLERK to the Governing Body, Battersea Polytechnic, S.W. 11. T 237

LEEDS TECHNICAL SCHOOL.
DEPARTMENT OF MECHANICAL ENGINEERING.
Lecturer Required, to Give Theoretical and Laboratory Instruction in Engineering Subjects, preferably with University or equivalent qualifications and experience of modern works methods. Commencing salary from £260 to £300 per annum. Written applications, with copies of testimonials, should be forwarded on or before 31st March, to the undersigned.
JAMES GRAHAM,
Education Offices, Director of Education.
Leeds, March, 1919. T 404

HERIOT-WATT COLLEGE, EDINBURGH.
MECHANICAL ENGINEERING DEPARTMENT.
Senior Lecturer in Machine Design, WANTED to take charge of Drawing Classes, Day and Evening, and lecture on Machine Design. Drawing Office and Workshop experience essential. Salary £350.
DEMONSTRATOR in ENGINEERING WANTED, Laboratory and Workshop experience desirable. Salary £150.
Applications and testimonials to be sent in to the PRINCIPAL not later than 22nd March. T 339

University of Bristol.—LECTURER in Electrical ENGINEERING. £300 - £10 - £350. For particulars and form of application, send at once, stamped, addressed, foolscap envelope, to the REGISTRAR of the Merchant Venturers' Technical College. T 321

Secretary Required by the BRISTOL WAGON & CARRIAGE WORKS COMPANY, LTD., Lawrence Hill, Bristol. One who has held similar position in a Public Limited Company. A F.C.I.S. or A.C.I.S. man preferred. Highest references required. Apply by letter. T 470

Engineer and Technical CALCULATOR, preferably B.Sc. with distinction in mathematics, and not over 35 years of age, WANTED for the Heavy Engine Department (blast furnace gas engines and large rolling mill engines). Must be well up in thermodynamics of steam and gas engines and turbines.—Address, stating age, training, experience, and salary required, H. PILLING, General Manager, GALLOWAYS Ltd., Engineers, Knott Mill, Manchester. T 439

Works Superintendent WANTED for works making railway material. Must be thoroughly conversant with latest practice, Forge and Machine Shop, medium size work.—Address, with full particulars, T 446, Offices of ENGINEERING.

Live Progress Man Required, for large repetition factory in Essex; previous experience essential; sound practical experience would be an asset.—Address, stating experience, age, and salary required, T 387, Offices of ENGINEERING.

Works Manager and Engineer for a South Staffordshire Tube Works, with full responsibility for manufacture and output. Good salary for right man. Applicants should state previous experience, age and salary required.—Address, T 394, Offices of ENGINEERING.

Wanted, a Manager, to take charge of a Bessemer and Open Hearth Plant in South Wales.—Address, giving full particulars as to age, previous experience and salary, T 213, Offices of ENGINEERING.

Mechanical and Electrical ENGINEER (must have good experience plant erection) REQUIRED, superintend erection milling plant on mine in South Ireland. Duration of job, six months; possibly retained afterwards. Free furnished bachelor's quarters in mess provided. Send copies testimonials and salary required for the six months.—Address, T 345, Offices of ENGINEERING.

Works' Manager Required for mass production of internal combustion engines. Must be a really live man capable of obtaining man capable of obtaining maximum production at minimum cost. State, full experiences and salary required.—Address, T 467, Offices of ENGINEERING.

Estimating Clerk and Rate FIXER REQUIRED for large steel foundry in South Midlands. Must be experienced and able to work without supervision.—Address, stating qualifications and salary required, T 344, Offices of ENGINEERING.

Assistant Director of PUBLIC WORKS REQUIRED by the Government of British Guiana for two years' service, with possible extension. Salary £700 per annum. No free passages or quarters provided. Maximum age 40. Candidates must have been First Assistants or have been in sole charge of works of considerable magnitude, and must possess administrative experience. They must have passed the A.M. Inst. C.E. examination, or an equivalent exempting examination, and be preferably corporate members of the Inst. of Mechanical Engineers.—Apply, at once (by letter), giving full details of qualifications, age and experience to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M/8807. T 346

Metallurgical Chemist WANTED, a first-class man with practical works experience, for large engineering works. Knowledge of carburising and heat treatment of steel. Analysis of steels, oils and greases.—Address, stating age, experience and references, T 384, Offices of ENGINEERING.

Wanted Immediately, a MECHANIC, experienced in the working and care of Diesel oil engines, to take charge of a water works pumping plant in quiet country district of Norfolk; dwelling house provided until new one is erected on works.—Apply, stating age, experience, wages required, with references and testimonials, to MANAGER, 2, York Road, Great Yarmouth. T 393

CITY OF BRADFORD.
ELECTRICITY DEPARTMENT.
MANAGERIAL ASSISTANT.

Applications are Invited for the POST of MANAGERIAL ASSISTANT in the Electricity Department of the Bradford Corporation.
The person appointed is required to assist the City Electrical Engineer and Manager in all matters appertaining to the managerial side of the Undertaking, and to be responsible to him for the immediate control of the clerical and storekeeping staffs.
Applicants must be well educated, and have received a sound commercial training in some large undertaking or firm, preferably engaged in the business of electricity supply or the manufacture of electrical machinery or apparatus.
The salary attached to the post is £500 per annum.
The successful candidate will be required to devote his whole time to the duties of the office, and to reside within the city.
Canvassing members of the Council will be a disqualification.
Lists of Duties and Forms, on which applications are to be made, may be obtained from MR. THOMAS ROLES, City Electrical Engineer and Manager, Town Hall, Bradford.
Applications, endorsed "Managerial Assistant—Electricity Department," accompanied by copies of not more than three testimonials (which will not be returned), to be sent in time to reach me not later than the first post on Thursday, the 27th March, 1919.
FREDERICK STEVENS,
Town Clerk.
Town Hall, Bradford.
10th March, 1919. T 393

CITY OF BRADFORD.
ELECTRICITY DEPARTMENT.
CHIEF ASSISTANT ELECTRICAL ENGINEER.

Applications are Invited for the POST of CHIEF ASSISTANT ELECTRICAL ENGINEER in the Electricity Department of the Bradford Corporation.
The person appointed is required to assist the City Electrical Engineer and Manager in all engineering matters, but principally in connection with the generation and distribution of electrical energy.
Applicants must have received a sound technical education, and have practical knowledge of the design and operation of electrical generating and converting plant and transmission and distribution systems.
The salary attached to the post is £750 per annum.
The successful candidate will be required to devote his whole time to the duties of the office, and to reside within the city.
Canvassing members of the Council will be a disqualification.
Lists of Duties and Forms, on which applications are to be made, may be obtained from Mr. THOMAS ROLES, City Electrical Engineer and Manager, Town Hall, Bradford.
Applications, endorsed "Chief Assistant Electrical Engineer," accompanied by copies of not more than three testimonials (which will not be returned), to be sent in time to reach me not later than the first post on Thursday, the 27th March, 1919.
FREDERICK STEVENS,
Town Hall, Bradford. Town Clerk.
10th March, 1919. T 392

Secretary Required by Firm of Steel Manufacturers in the North Midlands, Tool Steel, Castings and Forgings.
Some familiarity with the business is essential to the supervision of the commercial correspondence.
Address, T 116, Offices of ENGINEERING.

Wanted by The Consett Iron Co., Ltd., Consett, Co. Durham, WORKS ENGINEER of experience, also CONSTRUCTIONAL ENGINEER DRAUGHTSMAN of experience in iron and steel works, particularly on modern plant, and TWO ASSISTANT DRAUGHTSMEN similarly experienced.—Applications stating age, prior experience, copies of testimonials and salary required, to be sent to Mr. GEORGE, Beech Grove, Consett, Co. Durham, marking outside the envelope at top left hand corner which position the application is for. T 366

A Large Firm of Engineers in the Midlands, have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4250, Offices of ENGINEERING.

Wanted, an Engineer, to superintend engineering shops in connection with large steel works and collieries in south Wales.—Address, stating age, salary required, T 124, Offices of ENGINEERING.

Works Manager Wanted at once, to complete aircraft contracts and develop new undertakings in wood and metal work; modern works and machinery (south coast); splendid opportunity for energetic and practical man.—Send particulars of experience and salary required to BOX S. Z. 526, care of JACKSON'S, 19, Cullum Street, E.C. 3. T 401

Assistant Manager Wanted, by Shipbuilders and marine engineers in China, with technical and practical knowledge of modern shipbuilding and marine engineering; experienced in estimating; aged 32 to 40; three years' engagement.—Reply, by letter, detailing experience and salary required, to SHIPBUILDER, care of ABBOTTS, 32, Bastcheap, London, E.C. 3. T 408

Applicants for Appointment as Shipyard Manager on N.E.C., England, are now advised that the APPOINTMENT has been MADE. T 416

Wanted, for a large Marine Engine Works, a fully qualified ASSISTANT WORKS MANAGER. State age and experience.—Address, T 468, Offices of ENGINEERING.

Wanted, Assistant Engineer for Wireless Telegraph Design Department at Portsmouth. Applicants to have engineering degree and training. Salary £300 per year.—Replies to BOX 1774, WILLINGS, 125, Strand, London, W.C. 2. T 436

Chief Draughtsman Wanted, to take charge, under the manager, of large drawing office. Must have had control of men, design and detail drawings. Sugar-making machinery experience strong recommendation.—Address, sending particulars of training, qualifications, salary, T 382, Offices of ENGINEERING.

Draughtsman Required, with first-class steel and ironworks experience.—State full particulars and salary required, to SKINNINGROVE IRON CO., LTD., Saltburn, Yorks. T 380

Wanted Junior Draughtsman, some experience in internal combustion engines desired.—Apply R. A. LISTER & Co., LTD., Engine Department, Dursley. T 385

Draughtsman Required for Motor Design, to draw out mechanical details of electrical motors. Good experience necessary. Should be able to make own calculations as to strength of parts, bending moments and deflections of shafts, &c.—State age, experience and salary required to HARLAND & WOLFF, LTD., Belfast. T 383

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Draughtsmen, Several, with good general experience, REQUIRED at once by large industrial firm in the Midlands; permanent position and good prospects to capable men.—Address, giving full particulars of previous training and experience, age, salary required, &c., T 348, Offices of ENGINEERING.

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MELTING BRASS IN A ROCKING ELECTRIC FURNACE.

THE Bureau of Mines, Department of the Interior, United States of America, has issued a Bulletin* which gives a brief description of the electric furnaces in use or being developed in the United States for melting brass and then proceeds to describe the rocking furnace produced as a result of the experimental work carried out by the Bureau of Mines extending over a period of five years, finally giving a full description of the furnace built for commercial use in co-operation with the Detroit Edison Company, of Detroit.

The development of a furnace to supersede the usual coke-fired pot furnace is an important matter to the industry, due to the limitations imposed by the size of the crucible and the present cost of crucibles. The introduction during recent years of the larger capacity tilting type of coke and gas-fired crucible furnace has improved the position considerably, but these furnaces are still being developed and they are not suitable for a foundry where the quantity of metal melted per unit is small and only intermittent.

The report discusses the general problem of electric brass furnaces and especially the possibilities and limitations of an electric furnace of the rocking type. The types at present in use and on the market in the

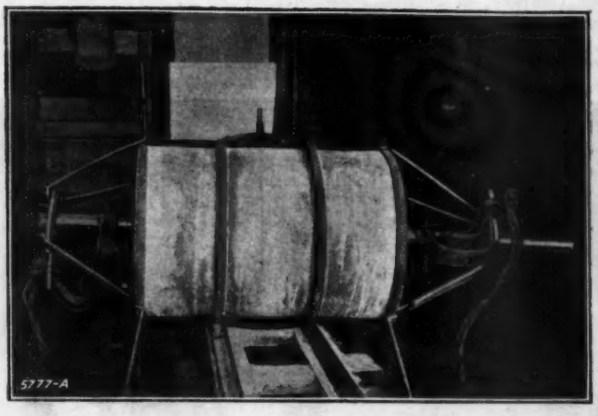


FIG. 1. THE EXPERIMENTAL LABORATORY ROCKING FURNACE.

TABLE I.—RESULTS OF TWENTY-EIGHT HEATS IN LABORATORY ELECTRIC ROCKING BRASS FURNACE.

Heat (Lab. No.).	Composition aimed at in melt.	Kind of material charged*	Weight of material charged.	Flux.	Condition of furnace at start.	Ingot poured.	Shot poured.	Total metal recovery.	Net loss of metal.	Temperature of pouring.	Total power consumption.	Power consumption per hundred pounds of metal
			lbs.			lb.	lb.	lb.	per cent.	deg. C.	kw.-hr.	kw.-hr.
L1	Yellow brass (2:1)	"2:1" yellow ingot	65·75	None	Cold†	58·6	3·0	61·6	6·45	1,075	33·5	51·0
L2	,, ,,	"25 per cent. zinc" ingot (55·4 lb.) and metallic zinc (6·4 lb.)	61·8	None	Hot‡	59·7	0·9	60·6	3·5	1,080	12·5	20·75
L3	,, ,,	"30 per cent. zinc" ingot (60) and zinc (3·6)	63·6	None	Nearly cold	61·0	0·7	61·7	2·05	1,100	19·0	30·0
L4	,, ,,	"30 per cent. zinc" ingot (60·5) and metallic zinc (3·1)	63·6	Common salt	Hot	62·0	1·0	63·0	0·95	1,090	14·5	23·0
L5	,, ,,	Ingot (60·95) and zinc (1·2)	62·15	Common salt	Cold	60·3	None	60·3	2·90	1,105	26·0	45·0
L6	,, ,,	Ingot (62) and zinc (0·6)	62·6	Common salt	Hot	61·8	0·6	62·4	0·30	1,095	12·5	20·0
L7	,, ,,	Ingot (60·3) and zinc (1·1)	61·4	Glass	Warm	60·0	None	60·0	2·25	1,100	18·0	29·5
L8	,, ,,	Ingot (61·7) and zinc (0·9)	62·6	Glass	Hot	60·75	1·25	62·0	0·95	1,090	14·0	22·5
L9	Yellow brass (25± per cent. zinc	Yellow "junk (46·7)," "kretz" (10), yellow gates (6·6), and scrap copper (3·5)	66·8	Salt	Cold	63·3	0·3	63·6	4·80§ 2·05¶	1,060‖	29·0	42·5
L10	,, ,,	Yellow "junk" (46·7), "kretz" (10), yellow gates (6·6), and scrap copper (3·3)	66·6	Salt	Hot	63·9	0·01	64·0	3·90§ 1·15¶	1,090	17·75	26·5
L11	,, ,,	Red gates (14·7), yellow chips (25), scrap copper (25), tin (1·25), and lead (1·05)	67·0	Glass	Slightly warm	66·1	0·5	66·6	0·60	1,250	28·75	43·0
L12	,, ,,	Red gates (20·05), yellow chips (25), scrap copper (25), tin (1·4), and lead (1·15).	72·6	Glass	Hot	70·7	0·3 1·8	71·0 from lining	2·20†	1,250	23·0	31·5
			139·6			135·8	2·6	139·4	0·20			
L13	Indeterminate	Dirty waste	50·0**	Salt	Cold	(43·6)	—	—	—	1,090	28·0	63·5
L14	Yellow brass (25± per cent zinc).	"25 per cent" ingot from heats L9 and L10 (63) and yellow gates (3·5).	66·5	Salt	Hot	66·6	0·2	66·8	0·30	1,150	15·5	24·5
L15	,, ,,	"25 per cent." ingot from heats L9 and L10 (64·2) and yellow gates (3·6)	67·8	Salt	Warm	67·0	0·3	67·3	0·75	1,150	18·5	28·5
L16	,, ,,	Yellow "25 per cent." chips (50) and yellow gates (4·9)	54·9	Salt	Hot	53·75	0·15	53·9	2·0	1,150	11·75	26·5
L17	Red brass (10± per cent. zinc).	Red chips (50) and red gates (4·15)	54·15	None	Hot	53·2	0·4	53·6	1·0	1,200	12·0	24·0
L18	,, ,,	Red gates	67·0	None	Cold	66·1	0·4	66·5††	0·75	1,200	35·0	52·0
L19	Yellow brass (25± per cent. zinc).	Yellow "junk" (70), yellow gates (10), "kretz" (15), and scrap copper (5).	100·0	Common salt	Cold	93·5	2·0	95·5	4·5§ 1·75¶	1,145	35·0	35·0
L20	,, ,,	Same as in L19	100·0	Common salt	Hot	91·15	0·7	95·85	4·15§ 1·40¶	1,145	24·2	24·2
L21	,, ,,	Same as in L19, plus (5·3) of gates	105·3	Common salt	Hot	100·9	0·7	101·6	3·55§ 0·80¶	1,175	21·0	20·0
L22	,, ,,	Same as in L19	100·0	Common salt	Hot	95·15	1·1	96·25	3·75§ 1·00¶	1,135	21·0	21·0‡‡
L23	Indeterminate	"Kretz"	50·0	None	Hot	40·2	1·1	41·3	17·4§	1,210	15·0	30·0
L24	Yellow brass (2:1)	2:1 brass ingot (37·8) and copper ingot (43·2)	103·5	None	Cold	101·0	1·3	102·3	0·75	1,075	30·5	30·0
L25	Red brass (10± per cent. zinc).	Red gates (21·5), yellow chips (37·5), scrap copper (37·5), lead (1·75), and tin (1·85)	106·15	None	Hot	104·95	0·70	105·65	0·50	1,200	25·0	23·6
L26	,, ,,	Red gates (21·5), yellow chips (37·5), scrap copper (37·5), lead (2·5), and tin (2)	107·3	None	Hot	106·0	0·7	106·7	0·55	1,200	21·2	20·0
L27	Yellow brass (25± per cent. zinc).	Yellow chips	100·0	Common salt	Hot	98·2	0·7	98·9	1·1	1,100	21·0	21·0‡‡
L28	Red brass (10± per cent. zinc).	Red chips	49·85	None	Hot	48·7	0·65	49·35	1·00	1,200	12·0	24·0

* Figures in parentheses refer to weight of material in pounds. † New hearth; furnace not rocked. ‡ Furnace rocked, only after spelter ing; bath in contact with new lining.
§ Apparent loss, based on weight of material charged. ‖ Temperature was too cold for good pouring. ¶ Actual loss, based on estimated weight of metallic material in charge.
** Includes dirt. †† Held in furnace one hour before pouring. ‡‡ Furnace was charged while hot from previous run, then stood about one hour before current was turned on.
Kretz—Dirty oxidised shot recovered from ashes and spillings by concentration. Junk—Scrap metal of a light nature.

* "Melting brass in a Rocking Electric Furnace." By H. W. Gillett and A. E. Rhoads. Bulletin No. 171 of the United States Bureau of Mines. Washington: Government Printing Office. [Price 20 cents.]

United States are the Ajax-Wyatt, the Baily, the Rennerfelt and the Snyder—to these has now to be added the rocking electric furnace, whilst the Foley, the General Electric and the Northrup are undergoing commercial tests. All of these furnaces are briefly described in the Bulletin and references are given to technical papers, patent specifications, &c., from which fuller information may be obtained.

The Bureau of Mines concluded from their own preliminary tests and from the experience of others that the indirect-arc type of electric furnace should show better results than the direct-arc type on account of its capacity for dealing with alloys higher in volatile constituents. Further, they decided to include a mechanical stirring device; by so doing they expected to reduce the loss when melting non-ferrous metals high in zinc contents, to avoid superheating the surface layer, to increase the efficiency and the rate of heat input.

The theoretical advantages of a rocking furnace when the charge has been melted are given as follows: (1) The charge would be thoroughly mixed and overheating of the surface prevented. (2) By washing the walls with the charge, the heat that the walls have absorbed from the arc by radiation will largely be given up to the metal. (3) The walls being washed by the molten bath, cannot become much hotter than the metal itself; this should prolong the life of the linings and lower the cost of maintenance. (4) With arc heating, the electrodes can be replaced at once whilst the furnace is hot.

The Bureau being unable to obtain a furnace for the experimental investigation which would meet their requirements, decided in the first place to build one on cheap lines. This, the laboratory rocking furnace, is shown in Fig. 1; the drum was 22 in. outside diameter by 32 in. long, and was provided with two heavy rings or hoops, upon which it was revolved on the track. The furnace was lined with circular fireclay tiles 3 in. thick, with a coating ½ in. thick of a mixture of fireclay and graphite. The graphite electrodes fitted into holes in the ends of the drum; they were 2 in. diameter by 40 in. long, and were adjusted by hand. The furnace was rotated by hand and the track raised so that the pouring could be effected direct from the spout into the moulds. The electric supply to the furnace was by flexible leads clamped on to the electrodes; the voltage on the furnace varied from 50 volts to 75 volts, and the current from 500 amperes to 700 amperes, the usual power input being about 30 kw. and the power factor averaged 80 to 90.

It is not possible in the space available, to give the particulars of all the experiments carried out on this laboratory furnace, but the summary contained in Table I, page 329, gives the results of 28 trials on the compositions of metal detailed in column 3. The power consumptions are given in column 12, whilst in column 13 the electric power supplied to the furnace has been calculated for a standard charge of 100 lb. of metal.

In order to further investigate the question of power consumption, a few tests were carried out with a charge of metal approximating to the full capacity of the furnace. Each charge consisting of 94 lb. of red and yellow ingot and 33 lb. scrap copper, the desired composition of the cast being 81·5 per cent. copper, 8·5 per cent. zinc, 6 per cent. lead and 4 per cent. tin; the charge was put into the furnace at the start and no further opening of the furnace was necessary.

The results of the five trials are summarised as follows:—

Weight of charge	639·55 lb., average of 128 lb. per charge.
Time arc on	46 minutes.
Pouring temperature	1,200 deg. C.
Average power input	36 kw.-hours.
Total number of kilowatt-hours used	136·5.
Power consumption in kilowatt-hours per 100 lb. of metal charged	21·5.
The consumption of electrodes during these five trials was ...	1 lb.

The result of the laboratory trials on the melting of brass and, further, the smaller tests to ascertain the behaviour of the rocking type of furnace when melting charges of such materials as manganese-bronze borings, nickel brass and copper for castings, were so promising that it was considered desirable to design and thoroughly test a larger furnace of this type when worked under commercial conditions.

The Bureau of Mines arranged to undertake the work and to co-operate in the development with the Detroit Edison Company, of Detroit, Michigan, the designs for the large commercial furnace being prepared by the Detroit Electric Company from sketches furnished by the Bureau. The furnace was built by the Detroit Electric Company, who were responsible for this, the supply of the electrodes, refractories, and undertook to supply the electric power for the tests; but the furnace was erected in the works of the Michigan Smelting and Refining Company, of Detroit, who undertook to furnish the labour for lining the furnace, the water for cooling the electrodes, the accessories for pouring the metal and the supply of the metal for charging the furnace. The tests were superintended throughout by representatives from the Bureau.

By this co-operative agreement it was possible to arrange for a comprehensive and practical series of trials, the expenses were distributed, and a most important point, the designers, the user of electric furnaces for melting non-ferrous metals, and the power company who supplied the electrical energy, were closely allied and interested in seeing that the investigation was carried through in a practical and commercial manner

In Figs. 2 and 3, annexed, are shown views

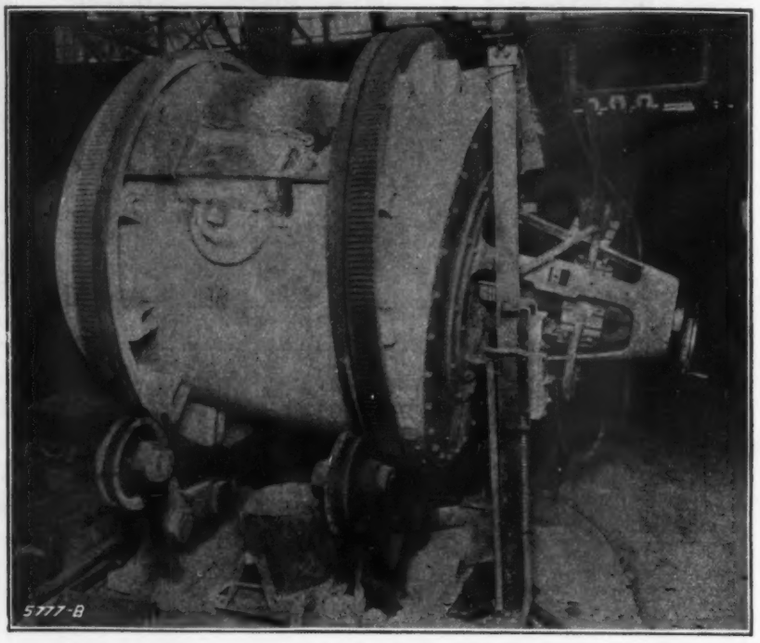


FIG. 2.

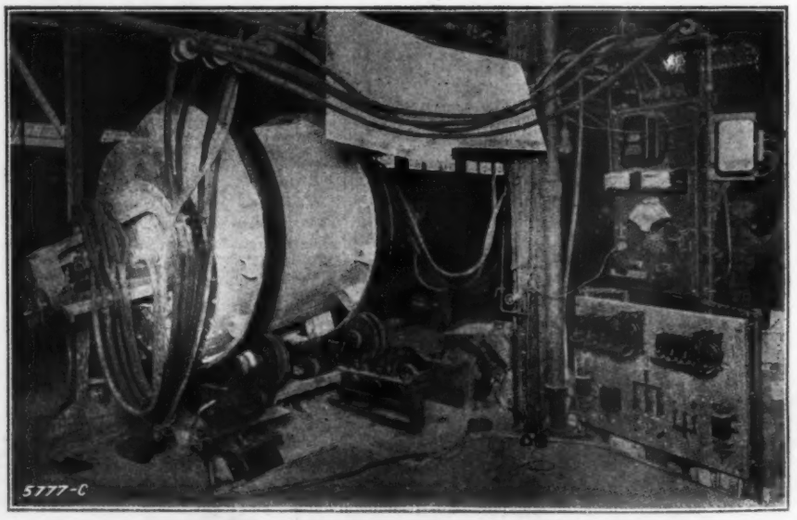


FIG. 3.

FIGS. 2 AND 3. COMMERCIAL ROCKING FURNACE.

of the commercial furnace. The furnace has a cylindrical iron shell, 5 ft. diameter by 5 ft. long, and is lined with an inner layer of "corundite," 4½ in. thick, laid in corundite cement, this layer being brought out of the shell around the door and round the holes through which the electrodes pass. At the back of the corundite was a layer, 4½ in. thick, of heat-insulating brick laid in asbestos cement, and behind this a layer, 3 in. thick, of infusorial-earth brick and infusorial-earth cement. This gives a lining 12 in. thick, leaving the hearth chamber 3 ft. diameter by 3 ft. long. The normal

capacity of the furnace was rated at 1,500 lb. (the furnace will take a charge of 2,000 lb.), but the usual charge was 1.300 lb. to 1,320 lb.

The rocking of the casing is effected by a motor (see Fig. 3), which drives the pinions gearing into the circular racks. At first the furnace was tilted within these racks, as illustrated in Figs. 2 and 3, but after a few trials this additional stirring motion was abandoned, and the drum set level. The motor is of 11 h.p. This was found to be in excess of the power required, as on test the power did not exceed 5 h.p.

The diagram, Fig. 4, indicates the positions of the furnace during the melting-down period, the "safe rocking" period (about 80 deg., and taking about 13½ seconds for a complete cycle), the "full rocking" period (about 200 deg., and taking about 33½ seconds for the cycle), and the period for pouring. The rocking stirs the metal thoroughly, but the amount of rocking given to a charge is governed by the state of the melt in the furnace; thus the change from the "safe rocking" to the "full rocking" is only made when most of the charge is melted, thus avoiding possible breakage or damage to the electrodes.

The rocking accomplishes four important functions:—

1. Prevents surface superheating and consequent zinc losses.
2. Thoroughly mixes the metal.
3. Cools the refractory lining to the temperature of the metal, thus increasing the lining life and decreasing the radiation losses and hence the power consumption.
4. Makes close temperature control possible by minimising the storage of heat.

When the charge is ready for pouring the operator cuts off the supply to the rocking motor and cuts in the pouring switch, which controls a portable reversing switch. This switch is carried by the operator who controls the furnace and allows him to get a full view of the stream and the ladle.

The graphite electrodes are 4 in. in diameter, with threaded nipples for continuous feeding, and are water cooled.

The power supply was taken from one phase of the Detroit Edison three-phase, 60-cycle, 4,600-volt circuit. Three 100-k.v.a. transformers were used to step down from 4,600 volts to 110 volts, and the voltage was then boosted up to 131 volts by means of a 50-k.v.a. transformer. The furnace was found to work satisfactorily at any voltage between 115 volts and 140 volts. During the early trials it was found necessary to introduce a reactance (made up of four turns of a pair of 750,000 cm. cables); this reduced the amount of current on dead short circuit; it further reduced the surging and amount of attention required on the arc.

The switchboards for controlling the supply and registering the amount of current taken by the furnace and motor are shown in Fig. 3.

The cost of the experimental installation is given, on the basis of the prices ruling for materials in the early part of 1918, at about 1,000*l.*, and includes the complete furnace, transformers and switchboards.

The reports of the trials carried out on the commercial furnace are very full, and many points have been investigated to clear up any difficulty or irregularity in the working of the furnace. These have been summarised by the reporters, but we can only briefly deal with the leading notes under the headings adopted by them.

Method of Charging.—It was found desirable to place the whole charge in the furnace at the beginning, rather than to melt part, then open the furnace and add the rest. With light materials it is immaterial whether or not this piles up above the electrodes. With ingots or bundled scrap the pieces must be placed where required by means of a charging paddle. Lead and zinc should be added with the main charge.

Electrode Consumption.—The actual consumption was under 2 lb. for each ton of metal melted; to this must be added an allowance for loss through breakage; equal to the actual consumption will certainly be ample.

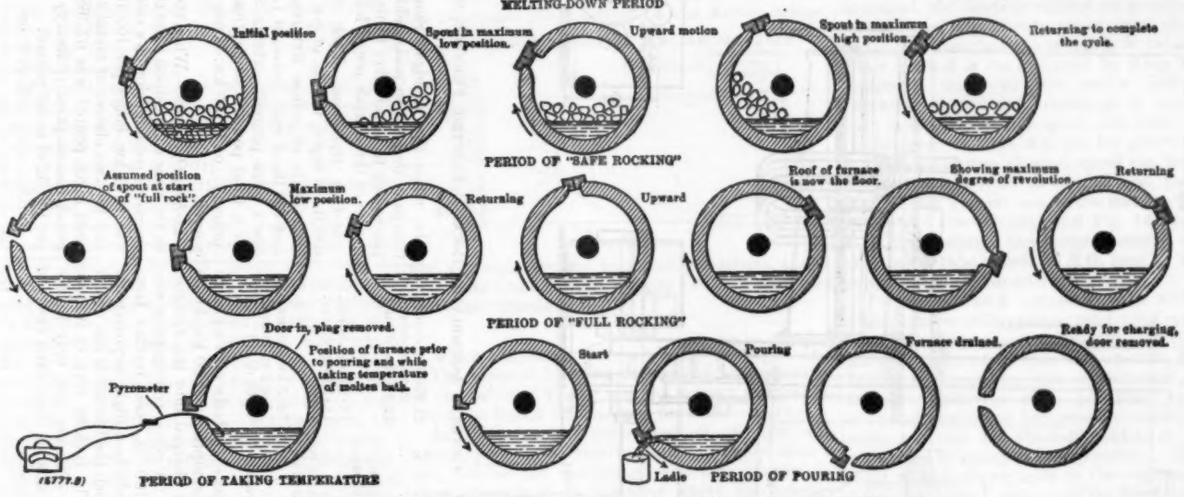


Fig. 4.—Diagrams showing positions of furnace during melting, rocking, and pouring.

Lining Life and Cost.—The cost of the lining materials for the furnace was about 60*l.*; the cost of labour must be added; it took a furnace mason and two helpers about five days to complete the work. After heat 218, when about 240,000 lb. of metal had been melted, the whole lining was examined and found to be still good, though showing some wear. The repairs carried out are reported as of a minor nature; for instance, at heat 77 some of the lining fell from the roof, again at about heat 177 some slagging off was noticed.

Behaviour of the Arc.—When the furnace is cold the arc is snappy, and this continues until the lining is at a low red heat, but with reactance any arc voltage from 105 volts to 140 volts on open circuit, and 95 volts to 125 volts under load, the arc was well behaved, and with the furnace working at full running temperature the arc will run smoothly and quietly.

The presence of a non-conducting vapour such as oil vapour makes the arc difficult to hold; again, zinc vapour has a marked effect, but with care and proper attention to the rocking of the melt this trouble can be kept well in hand.

Some trouble was experienced with the sticking of the electrodes in the hole or bush through which they are passed into the furnace; this was particularly so when the metal contained a high percentage of zinc. Tests were carried out to study this, but they were inconclusive; in the report, however, it is stated:—

"The results of the experimental work so far indicate that after a few weeks' development of the rocking furnace under rolling-mill conditions, it should melt alloys high in zinc as satisfactorily as the various other alloys so far melted in quantity in this furnace."

Output and Labour Costs.—One man can work the furnace, except when it is being charged, when a helper is necessary for part time; this is on the assumption that the materials are delivered at the furnace and the melted metal carried away by a separate pouring gang. It is stated that the labour costs per ton of output will not be higher for the electric furnace than for the coke-fired furnaces.

Character of the Metal Produced in the Furnace.—Frequent analyses of the product were made by the Michigan Smelting and Refining Company during the early stages of the tests, but the laboratory tests were dropped when it was found that the results were uniform. The examples given in the subjoined Table are characteristic:—

Metal Losses.—The metal-loss figures given in the report are merely comparative, as the charges were oily borings, and some dirty scrap, the actual metallic content not being known.

Two comprehensive tables are given in the report, the first giving full particulars of the charges, with the losses of metal on melting in the electric furnace compared with the losses for coke-fired pot furnaces on the same charge. In the second table, the charges are arranged in the order of copper content. From the statement made at the bottom of this table it would appear that a total of 204,461 lb. of metal of the various compositions given, were charged into the furnace; the yield or metal poured from the electric furnace was 1·15 per cent. higher than that from the coke fires. The reporters also state that, "Broadly speaking, the higher the zinc content of the alloy and the larger the proportion of borings in the charge, the greater is the metal saving in electric melting compared with melting with coke fires."

—	Copper.	Tin.	Lead.	Zinc
	Per cent.	Per cent.	Per cent.	Per cent.
Composition sought ..	76	8	13	3
Electric furnace, product	75·9	8·3	13·1	2·7
Composition sought ..	85	5	5	5
Electric furnace, product	85·2	4·9	4·8	5
Composition sought ..	67	1	2	30
Electric furnace, product	66·6	1	2	30·4

Power Consumption.—The watt-hour meter was installed on the secondary side of the transformer at the furnace switchboard, but the factor was obtained by test, by which the quantity of primary current could be calculated, and in the tables attached to the report the consumption of power

MELTING BRASS IN A ROCKING ELECTRIC FURNACE.

Fig. 5.

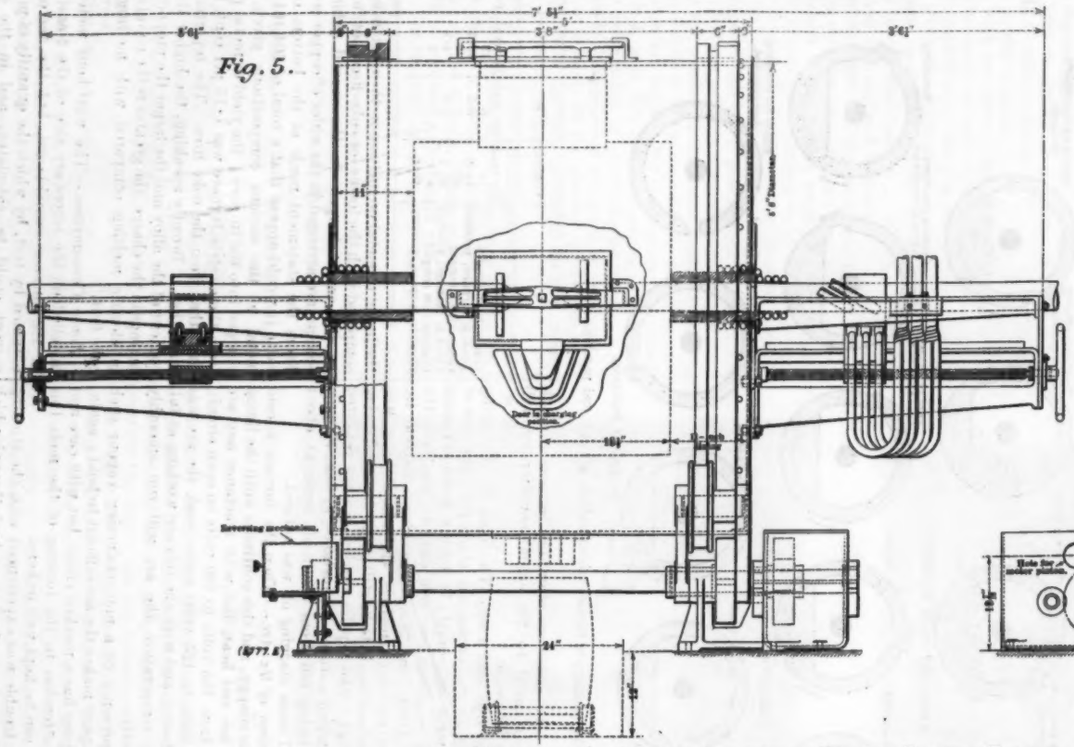
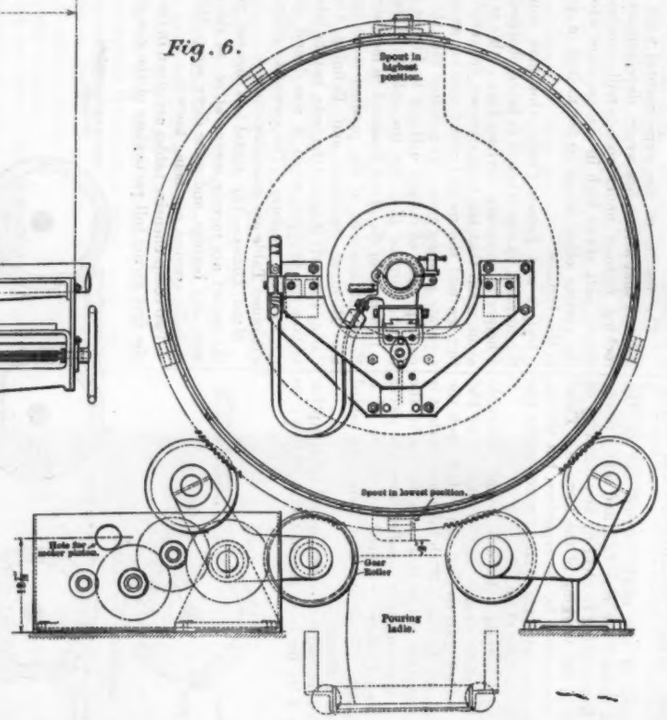


Fig. 6.



FIGS. 5 AND 6. GENERAL ASSEMBLY OF ROCKING ELECTRIC FURNACE AS REVISED.

has been stated in terms of the primary input and secondary metering.

From the figures given it will be seen that the power consumption is influenced by the condition of the furnace, *i.e.*, whether cold or hot at the commencement of the run, the length of the working day, and number of melts per day, the composition of the charge and the oil content of the material. The figures given are comprehensive, but we are unable to reproduce the full records here. The following summary of power consumption is therefore given of a trial extending over 22 days :—

Average Power Consumption during a Run of 22 Days.

Number of heats	103.
Quantity of metal charged ...	135,256 lb.
Average charge	1,313 lb.
Total time	198 hrs. 55 mins.
Average time for days' run ...	9 hrs. 03 mins.
Average time per heat ...	1 hr. 56 mins.
Weight of metal poured ...	131,105 lb.
Total gross metal loss	4,151 lb.
Total gross metal loss per cent.	3·07 per cent.
Power consumption, primary circuit (cal.)—total	24,346 kw.-hours.
Power consumption, secondary circuit (metered)—	
Arc	21,896 kw.-hours.
Motor	334 kw.-hours.
Total	22,230 kw.-hours.
Average power consumption per 100 lb. of material charged—	
Primary circuit	17·90 kw.-hours.
Secondary circuit	16·50 kw.-hours.
Average power consumption per 100 lb. of metal poured—	
Primary circuit	18·5 kw.-hours.
Secondary circuit	17·0 kw.-hours.
Average pouring temperature..	1,160 deg. C.

Effect of Size of Charges.—On tests with a charge of 622 lb. the power consumption was 20 kw.-hours per 100 lb. of material charged into the furnace, on the 1,313 lb. charges the power consumption was 17·90 kw.-hours per 100 lb., and further tests indicated that there would be a slight improvement over the latter figure when the furnace is run nearer to its full capacity. The rocking type of furnace promises to show fair efficiency not only in the larger sizes, but in the smaller sizes, even down to sizes of, say, 500-lb. capacity.

On the conclusion, in November, 1917, of the tests conducted by the Bureau of Mines, the furnace was shut down and allowed to lay idle until April, 1918, when the Michigan Smelting and Refining Company decided to make additional trials before proceeding to instal other furnaces of the type ; the results of these trials are as follow :

10-*hour Operation.*—Each charge consisted of 600 lb. of ingot, 200 lb. of red borings (1 per cent. oil), 50 lb. of yellow fixtures, 344 lb. of copper and 106 lb. of lead—total, of 1,300 lb. Twenty-six heats were poured, yielding 33,121 lb. of metal for a total power consumption of 5,922 kw.-hours (primary), or 17·85 kw.-hours per 100 lb. of metal poured.

24-*hour Operation.*—When the furnace was worked on the same composition as on the 10-hour operation, the power consumption on a total charge of 16,965 lb. was 13·3 kw.-hours per 100 lb. of metal charged, and for two classes of metal the total quantity of good ingot poured was 67,568 lb. The average power consumption (primary) was 13·2 kw.-hours per 100 lb. of metal poured.

Further trials followed, one series to investigate the sticking of the electrodes and the melting of metal high in zinc contents.

On the completion of the trials all the available information was studied by the Bureau of Mines and the Detroit Edison Company, and the design of the furnace revised. The general assembly of the latest type of furnace is shown in Figs. 5 and 6. The main change is in the increased internal diameter of the chamber, from 36 in. to 45 in., in order that the capacity may be 2,000 lb. The charging door, also, is improved to facilitate charging, and the electrode holders and the support for the slide altered to allow more rapid and convenient handling, and to permit drawing the electrodes right back when charging, a sleeve or packing being used to prevent sticking of the electrodes. Ten furnaces to the revised design are in course of construction.

THE GERMAN PETROLEUM INDUSTRY.—The German Petroleum Company has declared a dividend of 8 per cent., the Board not deeming it advisable to declare a higher dividend under the present troubled conditions, especially considering that the Roumanian Government had placed the Steana Romana under its control. The Board, however, considered the position of the company as sound as it had been before. Shares and bonds figured in the balance-sheet for about 44,000,000 marks ; it had been stated that they represented a value of 120,000,000 marks, but this was an estimate.

THE MEASUREMENT OF FLUID VELOCITY AND PRESSURE.

By J. R. PANNELL, A.M.I.M.E., F.R.Ae.S.

(*Continued from page* 297.)

HOT WIRE ANEMOMETERS. CLASS III.

The measurement of the motion of a gas by means of its cooling effect on a heated wire has been investigated by independent observers in England, Canada, United States of America, Italy and Germany. Experiments were carried out in England by Shakespeare in 1902, and Morris* about 1912; in the United States of America, the subject was receiving attention from Kennelly, Wright and Van Blyevelt† in 1909; in Canada from King‡ in 1914; and in Italy from Bordon§ in 1911. It will be sufficient for the purposes of the present article to describe the investigations of King and Morris.

The paper referred to above by Professor L. V. King, F.R.S.C., of McGill University, Montreal, constitutes a detailed theoretical examination of the convection of heat from small heated cylinders in a stream of fluid. The following approximate formulæ are finally given for H, the heat lost per unit length of cylinder.

(Low velocities) $H = 2\pi\kappa\theta_0/(\log b/a)$

(High velocities) $H = \kappa\theta_0 + 2\sqrt{(\pi K S \sigma a)}\, V^{\frac{1}{2}}\theta_0$,

where κ, σ, and S are respectively the thermal conductivity, density, and specific heat per unit mass of the fluid which is moving with velocity V; θ_0 is the temperature difference between the cylinder of radius a, and the unheated fluid. b is given by the formula $\kappa e^{1-\gamma}/(S\sigma V)$ in which γ is Eulers constant 0·5771.

These formulæ are shown to be applicable between certain values of Vd (V is the velocity of the current and d the diameter of the wire). Using centimeters and seconds the value of Vd which limits the range of the two formulæ is 0·0187; below this value the formula for low velocities must be used and above it that for high values.

For anemometry under ordinary conditions therefore, the heat lost by convection from a wire maintained at constant average temperature may be regarded, to a first order of approximation, as varying as the square root of the product velocity times density. An experimental investigation was also carried out by King on platinum wires which varied in diameter from 0·001-in. to 0·006-in., observations being taken over a range of temperature and velocity. The heated wire was moved through the air by mounting it on a whirling arm, the measured velocity being corrected for the "swirl" of the air set up by the rotation of the whirling arm.

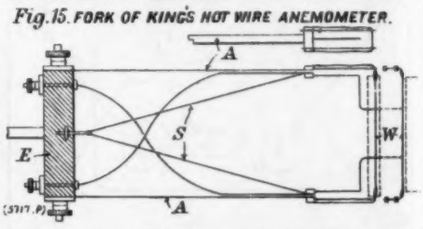
By this means a calibration curve was obtained from which the velocity could be determined from the current flowing in the wire. The resistance of the platinum anemometer wire was measured by comparison with a manganin resistance on a Kelvin double bridge, and the current flowing in the bridge on a standard Weston instrument which could be read to 0·0005 ampere. The temperature of the heated wire was calculated from its resistance.

Fig. 15 shows the fork upon which the heated wire was carried, the device being designed so as to create the minimum disturbance due to its motion relative to the air. The fork is described by Professor King as follows (see Fig. 15):—

"Fastened to a block of ebonite E are the two arms A of the fork, consisting of steel strips about 5 mm. in width. At the end of each is soldered a small brass block drilled to receive two fine needles fastened about 1 cm. apart. Threaded through the eyes is a 3-mil platinum wire having its extremities firmly clamped in the brass block just mentioned. The ends of the anemometer wire W are threaded through these two loops and secured in position by being twisted a couple of turns around the wire; the fundamental property of the Kelvin double bridge already referred to only requires the electric contact at these points to be moderately good. The tension in the wire is adjusted by a fine silk thread S, carried down from each of the brass blocks to an adjustable screw in the centre of the ebonite block; this thread is also effective in preventing lateral vibrations of the fork. Carried up from the ebonite block are two thin steel strips crossing each other to the opposite ends of the fork, insulated from each other and also from the fork by means of thin mica strips. These steel strips, which are held in position along the arms of the fork by two lashings of fine waxed silk cord, serve to brace the fork and at the same time serve as potential leads; at each end is soldered a small brass block drilled to hold a fine needle, at the extremity of which is soldered a short length of 6-mil platinum wire. To these are soldered one extremity of the 1-mil platinum potential terminals, the other being fused to the anemometer wire; this is most easily accomplished by connecting the wire to the bridge connections and adjusting the current until it is at a bright red heat; the potential wires are then brought to the required position and wound twice around the anemometer wire; by applying a slight tension while this is being done a satisfactory fused contact will be effected. The free end should then be broken or cut off close to the anemometer wire, so as to diminish the cooling effect of the potential leads. The heating to which the wire is subjected during this operation serves to anneal it sufficiently well for permanent use."

The method of using the anemometer is to adjust the heating current flowing through the wire, until the resistance (as measured on the Kelvin bridge)

Fig. 15. FORK OF KING'S HOT WIRE ANEMOMETER.



and consequently the temperature, attains a predetermined value. The velocity can be determined from the formula

$$i^2 = i_0^2 + k\sqrt{V},$$

in which i is the current and V the velocity.

The value of k can be determined by calibration at one value of V, and i_0 is the current required to bring the bridge into balance for zero velocity.

In discussing the advantages of the hot wire anemometer King remarks that "the pitot tube is not suitable for measuring variations of velocity close to surfaces or obstacles where the velocity gradient is extremely high, owing to the comparatively large size of the pitot tube orifice and the distortion of flow which it would cause under the conditions mentioned." He gives some results showing the distribution of flow at a distance from a rectangular slot 0·75 mm. wide through which air is being drawn; the velocity would be sensibly zero at less than 10 mm. from the centre of the slot and the supporting fork therefore well clear of the moving fluid. Using a 0·001-in. wire the disturbance of the flow would certainly be extremely small, but it is conceivable that under some conditions a pitot tube would offer less obstruction than the apparatus for the hot wire method. A particular instance which the writer has in mind is the measurement of velocity distribution across a section of a pipe through which fluid is flowing. Experiments on this subject have been carried out at the National Physical Laboratory by Dr. T. E. Stanton, F.R.S., the measurements being made by means of a small pitot tube, constructed of hypodermic syringe tubing, which could be set in any position across the pipe with an accuracy of 0·001-in. Observations near the wall were only taken on the side remote from that on which the pitot tube entered the pipe and under these conditions the obstruction consisted of the circular tube 0·03-in. external diameter which crossed the pipe, and the portion parallel to the axis about 0·4-in. long near the wall. The external dimensions at the rectangular mouth of the pitot tube were 0·013-in. along the radius of the pipe and 0·050-in. perpendicular to it, the velocity measured being an approximate mean value over an area of 0·00065 sq. in. It is possible that if the pipe were rectangular in cross section and the wall of the pipe consequently straight, the hot wire could be set parallel to it and measurements taken which would be mean values over a smaller radial distance than would be possible by means of a pitot tube. On the other hand it would appear that in a pipe whose cross section was circular it would be extremely difficult to maintain the anemometer wire in a curve parallel to that of the pipe with sufficient accuracy to allow measurements to be made at very short distances from the boundary. Further, the supports for the heated wire would necessarily be inside the pipe thereby causing considerable obstruction to the flow.

The apparatus developed by Professor J. E. MacGregor Morris was first described before the British Association at Dundee in 1912. The methods by which the apparatus is used may be divided into two classes, in both of which the wires are connected in the form of a Wheatstone bridge, one pair of opposite arms being the sensitive wires which are affected by the air current. The velocity is determined by (1) maintaining a constant voltage across the heated wires, the velocity being deduced from a measurement of the "out of balance" potential difference on the bridge caused by the change in temperature (and consequently resistance) of the sensitive wires, or (2) by maintaining the sensitive wires at a constant temperature (and therefore constant resistance); when the wind speed is increased, the heating current as indicated by the anemometer is gradually raised until the galvanometer indicates that the bridge is in balance. This latter method is the one used by King though the apparatus employed was rather different. As previously stated one advantage of method (2) is that calibration at one speed will suffice. Method (1) however, is more suitable for general use since a direct indication of wind speed can be obtained. Apparatus has been developed and patented by Morris* for general use in the measurement of air currents of low velocity, and Fig. 16, on page 334, is an illustration of the bridge mounted on the end of a metal tube about 2–1/2 ft. long by which it is supported in the air current.

This apparatus is connected to a millivoltmeter which can be calibrated to read wind speed direct. The early forms were constructed with the sensitive wires of platinum and the two opposite arms of the bridge of manganin; this combination gave satisfactory sensitivity since platinum has a high electrical resistance temperature coefficient while manganin can be obtained which is practically unaffected by changes of temperature. The arrangement was, however, open to the objection that the "out of balance" voltage on the Wheatstone bridge for a given air speed varied with the temperature of the air. This source of error has been removed in the apparatus illustrated by making all the arms of the bridge of the same material and shielding the alternate arms of the bridge from the air current so that their temperature is not reduced to the same extent as that of the pair which is fully exposed.

The material which has been used hitherto is platinum which has the advantage that it can be heated to a high temperature for special work. It has been the writer's privilege to have this anemometer explained personally by Professor Morris, who states that numerous other materials have been tried including iron, tungsten, carbon, nickel and heavily gilded iron wire.

Tungsten from a metal filament lamp is satisfactory, but the joints must be fused by an electric arc in a reducing atmosphere. The gilded iron wire is likely to be extensively used as it is easy to obtain and has a high electrical resistance temperature coefficient thus reducing to a minimum the power required to operate the apparatus. In the bridge illustrated in Fig. 16 the four wires are of platinum.

The apparatus may be easily understood by reference to Fig. 17, the diagrams of which are taken from the patent specification referred to above. The four heated wires, *c*, *d*, *e*, *f*, are stretched between, but insulated from, the plates *a*, *a*, the wires

* B.A. Report 1912 (ENGINEERING, December 27, 1912); ENGINEERING, August 8, 1913; British Patent Specification 25923/13.

† Trans., America M.I.E.E., June 28, 1909.

‡ Phil. Trans., Royal Society, 214 A., 1914, page 8373.

§ Proceedings of the Societe Italiana per il Progresso delle Scienze, October 18, 1911.

* Briti h Patent 25923/1913.

c and f being shielded from the air current by the tubes b, b. A second pair of tubes carries leads from o and n to the terminals j and k to which the indicator p is connected; these four tubes also serve as distance pieces to hold the plates a, a in their proper relative positions. The wires c and f are kept taut, when their temperature is raised,

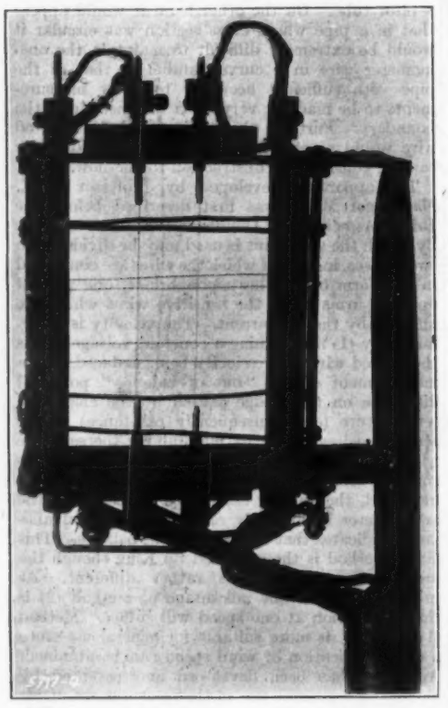


FIG. 16. MORRIS'S HOT-WIRE ANEMOMETER.

by means of the spiral springs shown in the elevation in Fig. 17; the same result is attained for the wires a and e by means of flat springs the ends of which can just be seen at the top of the apparatus in Fig. 16. The wires other than the two vertical ones of platinum, which appear in this illustration are placed there to protect the sensitive wires from mechanical damage.

The four heated wires are connected in the form of an ordinary wheatstone bridge in the manner shown at the lower part of Fig. 17. This form of apparatus is intended for use by the constant voltage method, the adjustable resistance r being provided as a means of compensating for the gradual drop in electro-motive force of the battery during its discharge. It should be noted however, that the "out of balance" potential difference of the Wheatstone bridge, which is used to indicate the wind speed, varies as the third power of the voltage applied to the bridge so that it is important, if high accuracy is required, for this applied voltage to be constant with considerable precision. For this reason an accurate millivoltmeter (preferably one with a low temperature coefficient) should be kept connected across the bridge and a constant voltage maintained by adjustment of the resistance r.

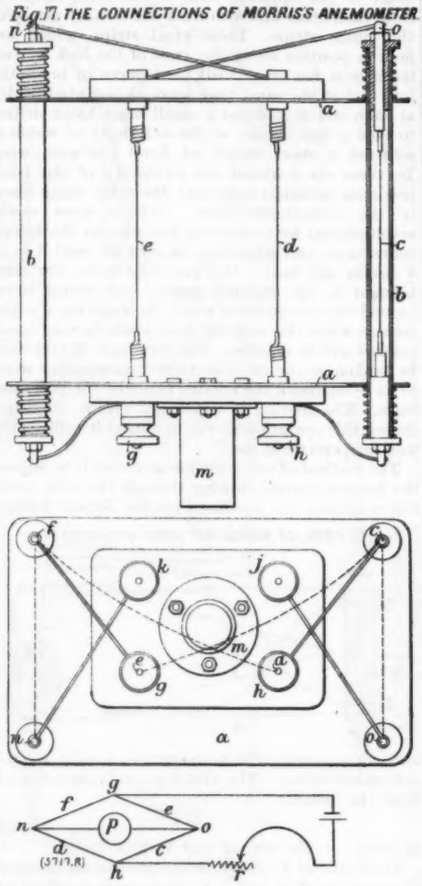
The adjustable resistance is the chief cause of the variation in the voltage applied to the bridge since the drop of voltage across it varies as the current flowing through it changes due to variations of wind speed. The magnitude of the adjustable resistance (and consequently the change in voltage due to it) can be reduced by using an Edison nickel accumulator which has a voltage of about 1·5 volts as compared with 2·0 volts for an ordinary lead cell.

Morris's patent specification provides for the use of a throw over switch by means of which the instrument which indicates the "out of balance" $p.d.$ can be used in series with a resistance, to measure the voltage across the bridge. The use of a "square-law" instrument, such as the Duddell thermoam-

meter, is recommended for an indicator as otherwise the scale of a direct reading instrument becomes compressed at the higher velocities.

It is pointed out that the anemometer can be used for indicating speed at a distance from the current of air. This anemometer appears to have a distinct field of usefulness as a direct reading

FIG. 17. THE CONNECTIONS OF MORRIS'S ANEMOMETER.



indicator of low velocity currents of air such as would be met with in coal mines, &c., or in the ventilation systems of public buildings.

(To be continued.)

THE BESSEL-CLIFFORD FUNCTION.

By G. GREENHILL.

WRITERS on stability, statical and dynamical, as of a beam, strut or whirling shaft, are compelled to introduce the Bessel function, to give a complete solution, and the ordinary function is then employed as given in the text-book.

But attention should be directed to a forgotten posthumous note by Clifford, in his "Mathematical Papers," 1882, page 346, where he makes a start with a function, which we may denote after him by $C(x)$, obtained as the sum of all the positive integral k powers of $-x$, $(-x)^k$, divided by the square of the fractorial k, Πk, and thus

$$C(x) = \Sigma (-x)^k / (\Pi k)^2,$$

but the exponential function

$$e^{-x} = \Sigma (-x)^k / \Pi k.$$

But there is this important difference, that whereas the exponential function never vanishes, the equation $C(x) = 0$ has an infinite number of positive roots.

The nth derivative of $C(x)$ is Clifford's

$$C_n(x) = \Sigma (-x)^k / \Pi k \, \Pi (n + k),$$

and the nth integral,

$$\Sigma (-x)^{n+k} / \Pi k \, \Pi (n + k),$$

is denoted by $C_{-n}(x)$, so that $C_{-n}(x) = x^n C_n(x)$.

Thence the differential equations

$$(1)\ d_x^{2n} x^n C_n(x) = C_n(x), \text{ and}$$

$$(2)\ d_x [x^{n+1} d_x C_n(x)] = x^n C_n(x),$$

$$\text{or } x d^2 C_n / dx^2 + (n + 1) d C_n / dx - C_n = 0;$$

$$\text{and } (3)\ J_n(2\sqrt{x}) = x^{-\frac{1}{2}n} C_{-n}(x) = x^{\frac{1}{2}n} C_n(x) = x^{\frac{1}{2}n} d^n C(x) / dx^n,\ J_0(2\sqrt{x}) = C(x).$$

Take the problem of the uniform chain, hanging vertically and vibrating slightly, investigated on the first page of "Bessel Functions," by Gray and Matthews, and again at the end of the book, where the density is taken to vary as the n-th power of x the height above the lower end. To realise the experiment it is easier to revolve the chain by hand, bodily in steady motion, and to investigate the permanent shape. When the deviation from the vertical is small, it is proportional to $C(x/l)$, or $C_n(n + 1)x/l$, where l is the height of the equivalent conical pendulum, and is the length of the subtangent at the lowest point, the free end of the chain. The plane vibration will then be shown in the shadow of the revolving chain thrown on a vertical wall.

In the Linear Differential Equation of the Second Order, reduced to the canonical form

$$\frac{1}{y} \frac{d^2y}{dx^2} + I = 0$$

where I is called its differential invariant, the solution is given by the Bessel or Clifford function when $I = k x^m$; or writing it

$$x^2 \frac{d^2 y}{d x^2} + k x^p y = 0,\ p = m + 2,$$

and changing to the variable $x = kx^p / p^2$, the differential equation changes to the (2) above for $C_n(x)$, with $n = -1/p$, as in ENGINEERING, page 99 *ante*, January 24, by Arthur Morley. This is the differential equation required in the investigation of the vertical stability of a mast or tree, and with $m = 1$, $p = 3$, for a vertical wire or uniform rod. Here n is fractional, and in Clifford's definition Πn must be taken to mean $\Gamma(n + 1)$, in Gauss's notation. Thus when n is half an odd integer, the Clifford functions are the derivatives or integrals of $\sin(2\sqrt{x} + a)$.

The Bessel function of real or imaginary argument, denoted by $(b\,e\,r)$ and $(b\,e\,i)$ in Kelvin's notation, are distinguished here by a mere change of sign in the argument x of the Clifford function.

To utilise the elaborate tables computed of the Bessel function, say of argument z, all that is required is a new column alongside of $x = 2\sqrt{z}$, as argument x of the corresponding Clifford function.

If writers on these questions of practical stability, which require the old Bessel function, will introduce these methods of Clifford and his function, they will notice a considerable simplification in their formulas, and they will give to the writer of the theoretical text-book a lead he will be compelled to follow.

BRITISH CONCRETE SHIPYARDS.

By W. NOBLE TWELVETREES, M.I.Mech.E., M.Soc.Ing.Civ.

YARDS AT BRENTFORD AND ROCHFORD (ESSEX).

IN this article, two concrete shipyards are dealt with, equipped by Messrs. J. and W. Stewart, and Messrs. Stewart and Partners, Limited, of London. The Brentford yard is of limited capacity, as only one vessel, not exceeding about 150 ft. in length, can be built there at a time. The Rochford yard is of far greater size, and the present equipment will provide for the simultaneous construction of three vessels up to nearly 200 ft. in length, sufficient land being available for future extensions.

As the system of construction adopted is the same at both yards, it will be convenient to give a brief outline of it at the outset, adding further details when describing and illustrating the work carried on at the two establishments.

In the Stewart system of concrete shipbuilding, the main characteristic is the employment of precast transverse frames, all other parts of the construction being moulded *in situ*. In the Brentford and Rochford yards of the firm, the vessels are built in dry docks so that they can be floated out on

completion without the customary operation of launching.

The first operation in the building of a vessel on the Stewart system is the advance moulding of the transverse frame as follows: The reinforcing bars and ties of the frames are assembled and secured in their correct positions, the skeletons so formed are placed in moulds built horizontally on the ground, concrete is deposited and rammed in the moulds, and a sufficient time is allowed to lapse for the hardening of the concrete. The pre-cast frames are subsequently hoisted and lowered into their predetermined places in the dock. The outer shuttering for the hull is then erected, being formed according to the outline shape of the frames. A space of about 4 in. is left between the frames and the shuttering to provide for the construction of the bottom and sides of the hull. In the midship portion of the vessel the frames are of U shape, and in the bow and stern portions they approximate to V shape, their configuration varying with the curvature of the hull. Fig. 1 shows the reinforcing skeletons for U and V frames ready for concreting.

The outer shuttering for the hull is erected after the pre-cast frames are adjusted and fixed in position. The moulds for keelsons, stringers and other members are assembled after their reinforcement has been placed and fixed, and the boards constituting the inner shuttering for the hull are laid progressively with the deposition and ramming of the concrete, which is delivered from the mixer by means of gravity shoots, discharging into shallow trays where the material is turned over by shovel before being deposited.

FIG. 1. REINFORCEMENT FOR PRE-CAST FRAMES; U-SHAPE FOR A MIDSHIP SECTION, V-SHAPE FOR A FRAME AFT.

From the foregoing outline, it will be seen that the Stewart system provides for the construction of the outer shell on the monolithic principle throughout, that a large proportion of the interior construction is also monolithic, and that the only joints intentionally made are those between the pre-cast frames and adjoining members afterwards moulded *in situ*.

The barges, under construction by Messrs. Stewart and Partners, are being built in general conformity with the plans and specifications of the Ministry of Shipping for classification by Lloyd's Registry. The specifications contain stipulations of the usual character relative to the quality and testing of the cement used, the proportions and preparation of the concrete, and the quality and testing of the steel bars employed as reinforcement. It is also required that test cubes and slabs shall be prepared for crushing and permeability tests, to be conducted by Messrs. Kirkaldy and Son, or some other approved firm, with the object of ascertaining the suitability of the concrete for ship construction. The minimum thickness of concrete as cover to the reinforcement is ½ in. on the outer surface of the hull next the sea water, and on the inner surfaces exposed to bilge or other water. With regard to surface treatment, the specifications permits the exterior to be rubbed over with sand and cement, but without doing anything in the nature of rendering. No provision is made for the application of paint or anti-fouling composition to the exterior of the hull, the object probably being to obtain data as to the behaviour of the concrete before adopting any form of protective coating. Before the acceptance of any vessel, leakage tests will be carried out on the maiden voyage, and if the results are unsatisfactory the builder will have an opportunity of remedying the defects. If subsequent tests are still unsatisfactory, the vessel may be finally rejected. Every vessel is to be finished complete ready for sea by the builder, all gear, fittings and stores being fixed or stowed away, as the case may be, and inventories of the equipment are to be prepared showing clearly where each article is fitted or stowed.

BRENTFORD SHIPYARD.

Concrete shipbuilding was commenced by the firm during the second half of the year 1917, in a yard between High-street, Brentford and the River Brent, which for upwards of a mile before its junction with the Thames is incorporated with the Grand Junction Canal.

The site is an excellent one in respect of transport facilities, being close to the River Thames, in direct communication with the Midlands by the Grand Junction Canal and within a stone's throw of the Great Western Railway goods depot. It provides ample space for workshops and yards, and includes a dry dock of size sufficient for the building of vessels up to about 150 ft. in length.

As only one vessel can be built at a time, the workshop accommodation required is not very extensive. The buildings at the yard include a carpenters' shop and mould loft for the preparation of profiles, shuttering and moulds, a bar bending shop where reinforcement is got ready for the pre-cast frames and the work moulded *in situ*, the form of all bent bars being verified on templates; stores for cement and sundries; and offices for the manager, foremen and timekeeper. The operations involved in the work of making the precast frames is carried on in a yard conveniently near to the dock, and derrick cranes are installed for handling the frames and materials generally. The yard is lighted throughout by electricity in order to permit the execution of work at night, and temporary roofing, with Belfast type trusses, can be erected over the dock during the winter months for the protection of the men and the work upon which they are engaged. The original dock has been widened and otherwise improved, and the gates open upon a wide bend of the river where there is an ample depth of water at high tide.

The first vessel, built entirely on the monolithic principle, has been in service for some months, and the second one, constructed with pre-cast frames as described, was floated and taken over by the Government on October 22 last.

The main dimensions of the barge with pre-cast frames are: Length between perpendiculars, 150 ft.; breadth, 24 ft. 6 in.; depth, 13 ft. 6 in.; and draught, 10 ft. 11½ in., the vessel having a displacement of 900 tons and a deadweight capacity of about 400 tons on a draught of 11 ft.

It is divided into five compartments by four watertight bulkheads. The fore compartment, with a maximum length of 18 ft., is intended for stores, and comprises a chain locker; the next three compartments, 32 ft., 43 ft. 6 in., and 32 ft. in length respectively, constitute holds for cargo, and the aft compartment, 18 ft. in length, provides quarters for the master and crew. A hand windlass and wire reel and other appliances for towing are provided on the deck at the bow.

With the object of facilitating close comparison between concrete and steel barges, the design of the hull is based on customary ship lines, a course of procedure which has added greatly to the cost of constructing the profiles and shuttering, and has also involved increased labour in actual building work. The results, however, have been vessels of pleasing appearance and, so far as can be judged, of superior strength and towing qualities. On Plate XIX we give a series of photographic views, Figs. 2 to 9, illustrating various stages in the construction of the 400-ton barge built at Brentford, from the erection of the outer shuttering to final completion.

The shell of the hull, 4 in. thick, is moulded without a single joint and also monolithic with the keelsons, stringers, bulkheads, decks, hatch coamings, intermediate decks and partition walls. The U-shaped transverse frames are 8 in. wide by 1 ft. 5 in. deep along the bottom and 1 ft. 2 in. from front to back in the parallel part of the vertical arms. They are spaced apart at distances ranging from 4 ft. 9 in. to 5 ft. 6½ in. in different parts of the vessel, and are incorporated with the monolithic portion of the structure in the manner already described. The keelsons, measuring 7 in. wide by 10 in. deep, are spaced 4 ft. apart, centre to centre. The lower stringers, 4 ft. 3 in. above the bottom, measure 7 in. by 9½ in. in cross-section, and the upper stringers, 4 ft. above the lower series, are 7 in. by 6 in. in cross-section.

The frames are further braced by the gunwale beams, measuring 1 ft. 4 in. wide, with a mean depth of about 1 ft., and also by the hatchway coamings, and where no hatchways occur they are completed at the top by horizontal extensions, acting as deck beams, thus converting the U-frames into quadrilateral structures, the V-shaped frames in the fore and aft compartments being similarly completed to triangular form.

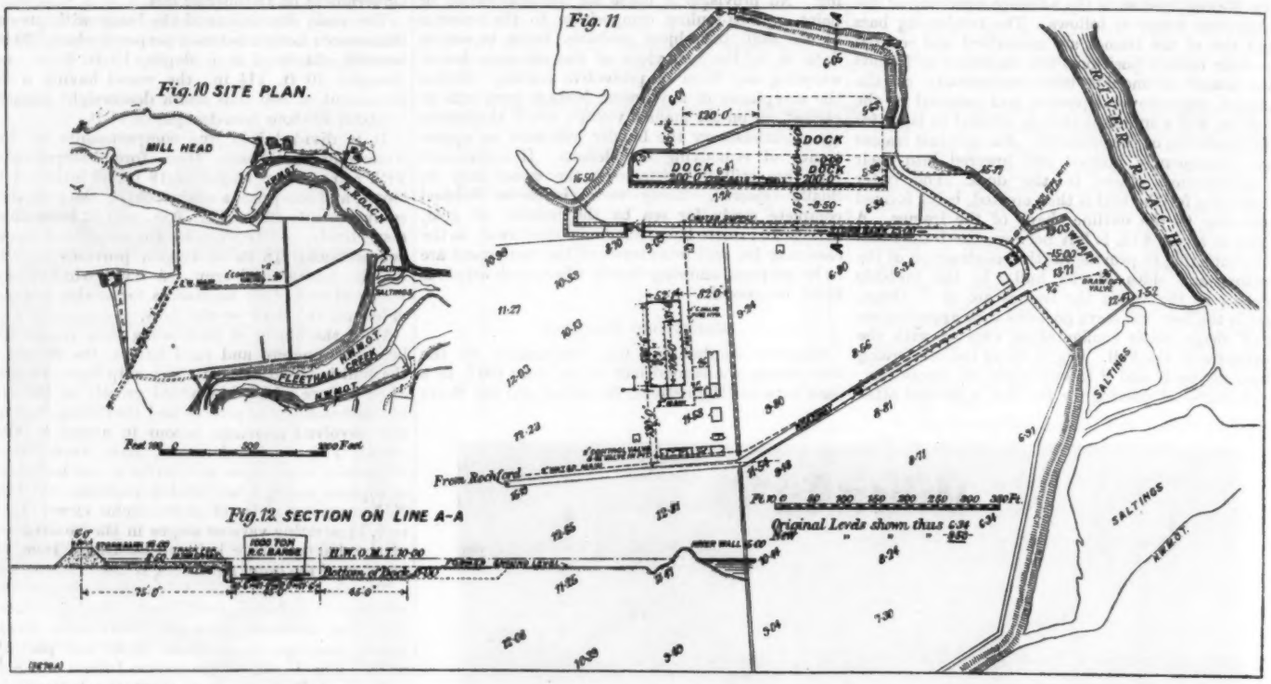
The bulkheads consist of a vertical slab, 4 in. thick, stiffened by counterforts, spaced 4 ft. apart centre to centre, projecting 10 in. on either side of the slab and being of the same thickness as the keelsons. All the members mentioned, together with the shell of the hull, the decking and the interior walls, constitute a framed structure of great strength and rigidity, with interlocked reinforcement and concrete of practically monolithic character throughout.

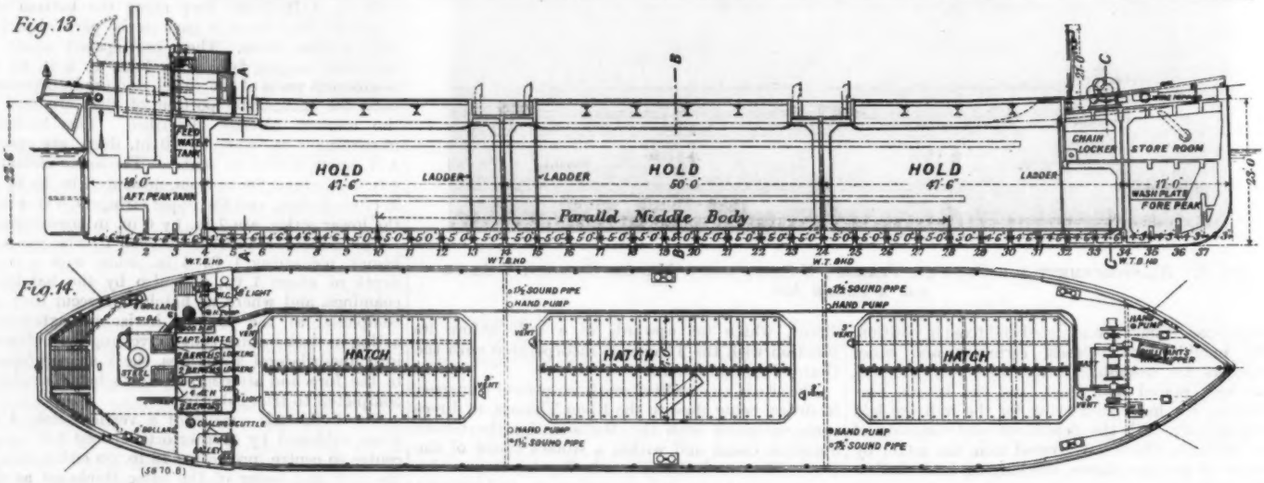
ROCHFORD SHIPYARD.

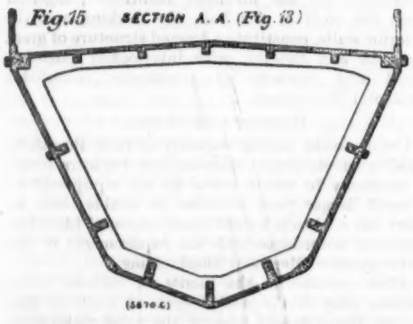
Owing to the limited capacity of their Brentford establishment, Messrs. Stewart and Partners found it necessary to secure a site for the equipment of a much larger yard in order to enable them to carry out contracts for the construction of 1,000-ton barges in accordance with the requirements of the Department of Merchant Shipbuilding.

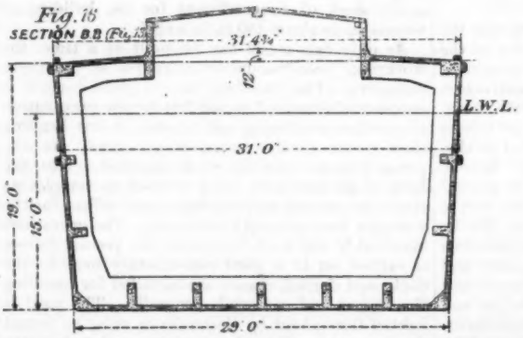
After considering the merits of various alternatives, they finally settled upon an excellent site on the River Roach, one of the tidal waterways communicating with the River Crouch, in Essex. Formerly occupied in part as a brickyard, the land covers an area of about 70 acres, and is bounded on three sides by the River Roach and a tributary named Fleethall Creek. The fourth side is in communication by road with the adjacent country town of Rochford and also with Southend-on-Sea, which is 3 miles away. Fig. 10, on page 336, is a site plan. At the outer end of the site the river

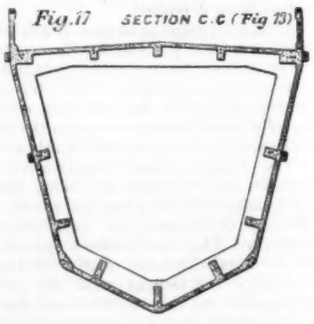
THE CONSTRUCTION OF REINFORCED CONCRETE BARGES; ROCHFORD SHIPYARD.











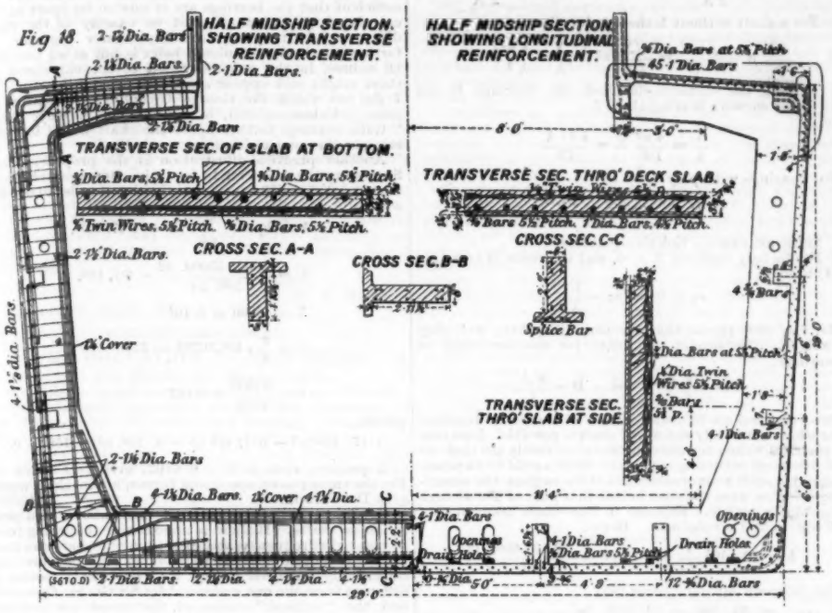
has a minimum width of about 250 ft. at high tide, and a fair depth of water, which can be increased by dredging if necessary.

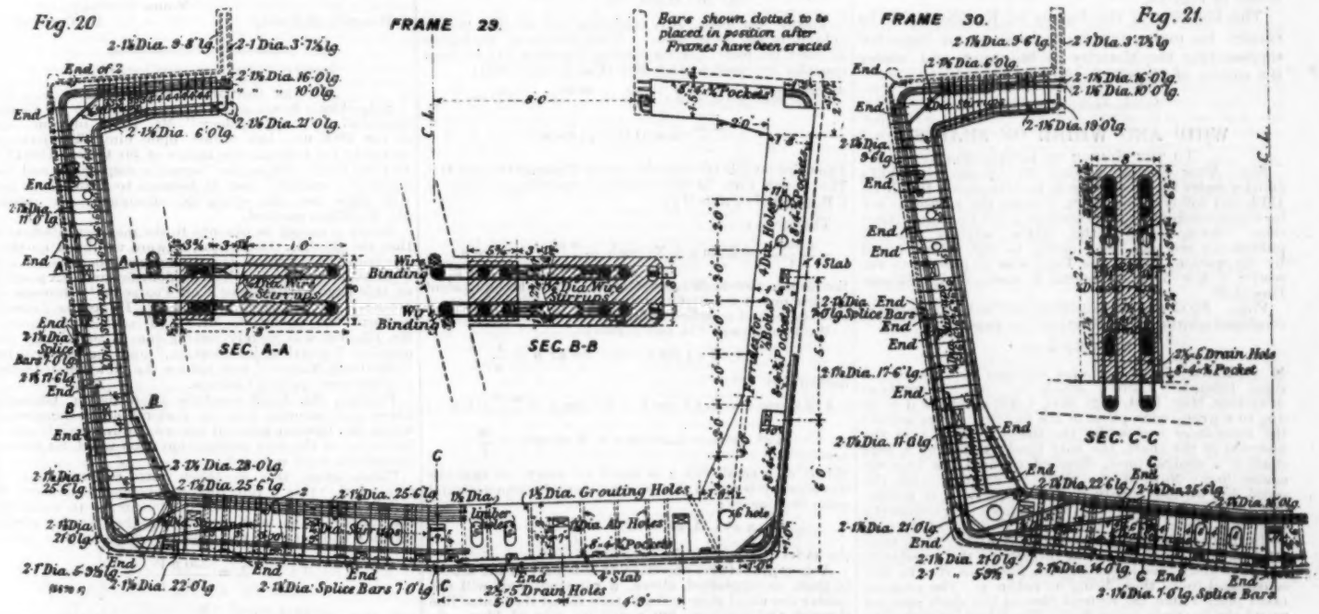
The laying-out and equipment of the yard was commenced during the early part of 1918, and the work is still in progress simultaneously with preparations for the construction of the first three 1,000-ton barges for the Admiralty.

As elsewhere in Essex on the borders of the sea and the Thames, the normal ground level is below high water mark, and the land is protected by a river wall, behind this being a storm bank. To illustrate the nature of the equipment covered by the scheme now in course of execution, we reproduce in Figs. 11 and 12 a complete plan and cross-section of the yard. The road from Rochford, shown on the left-hand side of Fig. 11, is continued across the site to a wharf having a river front of 175 ft., and a width of 125 ft. for the landing of materials brought to the yard by sea.

The general office building, 100 ft. long by 16 ft. wide, affords accommodation for the manager, draughtsmen, and clerks. It also contains a women's mess-room. A large building behind the

THE CONSTRUCTION OF REINFORCED CONCRETE BARGES; ROCHFORD SHIPYARD.





offices, measuring 136 ft. 6 in. long by 52 ft. wide, is occupied as a saw mill, joiners' shop, mould loft, and steel bending shop, power for driving machinery being furnished by a steam engine in an outbuilding, next to which is a smithy. The other buildings in this part of the yard include storehouses and a spacious mess-room for workmen. Cement is stored in a large shed on the wharf. Water mains have been laid throughout the yard, with service pipes to the various buildings, standpipes at points where water is required for concrete mixing and other purposes, and hydrants near the main buildings.

Yards of ample size are provided for the storage of timber and steel, and for continuing the preparation of shuttering, moulds and reinforcement beyond the preliminary stages of work conducted in the shops.

The area north of the storm bank shown on the plan is allocated to what may be termed the dock-yard, where a large dock has been excavated for building and fitting out ships, and a broad quay has been constructed along one side of the dock for moulding the pre-cast transverse frames, and supplying materials of all kinds to men at work in the dock.

Measuring 400 ft. in length and having a maximum width of 90 ft., the dock has a depth of nearly 8 ft., and will accommodate three 1,000-ton barges, communication with the river being provided by an entrance cut closed by a movable cofferdam. The original ground level is being raised, and the space between the concrete dock wall and the storm bank has been laid out as a quay and work yard, 500 ft. in length and 64 ft. in width. Along the front of the quay a track has been laid for a 10-ton travelling crane and a travelling concrete mixer, and a track of the same gauge runs along the front of the storm bank, the tracks being connected by a switch at one end. On the area between the tracks there are beds for the final preparation of moulds and reinforcement and for the concreting of transverse frames, concrete being supplied from the mixer travelling along the storm bank. After the frames have been erected and secured in the vessels to be built, concrete for completion of the latter will be delivered from the same or another mixer travelling on the dock-wall track, and discharged at required points by means of gravity shoots.

Simultaneously with the equipment of the yard, work was commenced several months ago in the preparation of profiles, shuttering, moulds, reinforcement and frames for the first series of 1,000-ton barges to be built in the dock, which was then in course of construction.

The form of the dock in plan, 90 ft. wide at the river end and only 45 ft. wide at the landward end, was decided upon in conformity with the programme of building work, which provides for the construction of two barges alongside the quay, the floating of the first vessel, on completion of the hull, to the berth opposite the cofferdam which closes the river cut, and the commencement of a third barge at the berth vacated. The side of the dock facing the third berth will be equipped as a fitting-out quay. The accommodation, plant and equipment described, and shown by the plan reproduced,

represent a first instalment, further developments necessarily depending to a considerable extent upon the precise nature of future requirements in the way of concrete shipbuilding.

The barges under construction at Rochford, although embodying the same system as that adopted at the Brentford yard, are of more than double the deadweight capacity of those built at the latter establishment, and denote a further improvement in respect of design from the standpoint of naval architecture.

Figs. 13 to 17, on page 336, and Figs. 18 to 21, on page 337, give details of one of these barges. Figs. 13 to 17 includes a plan, longitudinal section and three cross-sections showing the dimensions and positions of the holds, hatchways, and the general arrangement of the members forming the framework of the vessel, which has a length of 180 ft., a breadth of 31 ft., at load-water level, a moulded depth of 19 ft. and a displacement of 1,810 tons at 15 ft. draught.

Fig. 18 gives two half-sections amidships, showing, respectively, the transverse and longitudinal reinforcement of the frames and adjoining parts of the construction, and also includes sections illustrating the details of the reinforcement in the bottom, side walls, decking and hatchway coamings.

Fig. 20 gives details of the first frame forward of the parallel portion of the hull, No. 29 in the longitudinal section (Fig. 13), and shows the nature of the provision made for the incorporation of the pre-cast frames with the monolithic part of the work. Figs. 19 and 21 give similar details of frame No. 30, the position of which will also be found in Fig. 13.

The building of the barges at Rochford will be carried on under the supervision of an inspector representing the Ministry of Shipping, and under the survey of Lloyd's Registry of Shipping.

WHIP AND WHIRL OF SHAFTS.

TO THE EDITOR OF ENGINEERING.

SIR,—After having studied Sir George Greenhill's articles under the above title in ENGINEERING, March 15, 1918, and following numbers, I wrote the author to ask for explanation of a few difficulties in his treatise. After some correspondence, the latter advised me to publish my remarks, but, owing to the delay caused by the war, it is only now I am able to present to the reader a few of the remarks I made to Sir George Greenhill.

First. Sir George Greenhill cites a "well-known law in combined whirling and vibration" on page 273:

$$N_1^2 + N_2^2 = N^2.$$

Now, although I know this law has long been considered right (compare Chree's article in the *Philosophical Magazine*, May, 1904, page 504), I still maintain it to be due to a wrong conception of the motion. If we neglect the resistances caused by the internal friction in the material of the shaft, the only force exerted by a bent shaft is a central force, directed towards the bearings centre line. Now, if the shaft be rotating with the speed N_1, we may easily find the equations of motion (see, for instance, "A. Föppl. Vorlesungen über technische mechanik, Band IV"), and we see that the shaft may be in natural vibration with speed N at the same time rotating with speed N_1. But (neglecting the unbalance, as Chree did) this latter motion gives no rise to any centrifugal force, there being no radius y. The rotation takes place round the neutral fibre of the shaft and not round the bearings centre line. The vibration may take place round this latter line. Vibration and rotation do not interfere with each other.*

Second. Sir George Greenhill starts the principal part of his article with the assumption that the shaft takes the form of a helix, and deduces the conditional equation for the possibility of this form. This equation (page 274, No. 4) is quadratic, and one would think this means there are two possibilities of equilibrium corresponding with two possible forms of helices. Sir George Greenhill's interpretation is that the single helix is to be replaced by a superposition of two helices, but for a shaft in this latter form the calculation does not hold good. All properties of the helix which Sir George Greenhill makes use of in arriving at equation (4) are no longer true for the deformed helix. I think it very clear that equation (4) gives *two separate* solutions like all quadratic equations, and not *one combined* solution. As a matter of fact, when dealing with the problem for a rotating shaft (on page 388, paragraph 14), Sir George Greenhill does not attribute to the quadratic equation this meaning of a deformed helix.

Equation (4)

$$A n^2 - L n - X = 0$$

gives

$$n_1 = \frac{L + \sqrt{L^2 + 4AX}}{2A} \text{ and } n_2 = L - \frac{\sqrt{L^2 + 4AX}}{2A}.$$

For a shaft without L these values become

$$n = \frac{\sqrt{AX}}{A} = \frac{\sqrt{X}}{A}, \quad n^2 = \frac{X}{A} = \frac{4\pi^2}{\lambda^2}.$$

Putting the distance between the bearings D, we have (for *encastre* bearings $D = \lambda$. or

$$\frac{X}{A} = \frac{4\pi^2}{D^2}, \quad X = \frac{4\pi^2 A}{D^2}$$

For bearings with play

$$D = \frac{\lambda}{2} \text{ and } X = \frac{\pi^2 A}{D^2}$$

These are exactly Euler's equations.

For factory shafting $X = 0$, and the roots of equation (4) become:

$$n_1 = 0 \text{ and } n_2 = \frac{L}{A},$$

the first root means that the shaft may very well stay straight. The second root gives for the two kinds of bearings:

$$D = \frac{2\pi A}{L} \quad \text{and} \quad D = \frac{\pi A}{L}$$

these expressions indicate certain distances of bearings for which a helically-deformed shaft is possible. Inserting numerical values for the constants, we easily see that for all distances occurring in practice there would be no possibility for such a deformed shaft if we neglect the centrifugal forces, as is the case in this first part of Sir George Greenhill's article. Suppose a 2-in. shaft transmitting 20 h.p. at 200 revolutions. Here:

$$A = 30.\ 10^6\ \frac{\pi}{64}\ 2^4. \qquad L = \frac{20.\ 33{,}000.\ 12}{200.\ 2\pi}$$

with bearings allowing some play:

$$D = \frac{\pi.\ 30.\ 10^6\ \pi.\ 2^4.\ 200\ 2\pi}{64.\ 20.\ 33{,}000.\ 12} \simeq 12{,}500 \text{ inches.}$$

Third. On page 387, equation (3) in the middle column is not quite clear. With reasoning analogous to that on page 274 for finding equation (1) we must consider the shaft section at C (Fig. 2, page 387):

$$\frac{A \sin^2 \alpha}{C} = L \sin \alpha + X C \cos \alpha + \frac{m a^2}{l} \sin \alpha\ \overline{OD} \cos \alpha - \frac{m a^2}{l} \sin \alpha\ (\overline{OD} - p) \cos \alpha$$

The third term is the force in section B parallel to axis O C. The fourth term is the resultant centrifugal force on C B, parallel to axis O C.

This gives:

$$\frac{A \sin^2 \alpha}{C} = L \sin \alpha + X C \cos \alpha + \frac{m a^2}{l} p \sin \alpha \cos \alpha.$$

Sir George Greenhill's equation (3) would be equivalent to this one if its first member were divided by cos α and its second member multiplied by cos α.

We know (page 274 and earlier):

$$C = a \sin \alpha; \quad \sin \alpha = n C \cos \alpha; \quad p = \frac{1}{n}$$

and so find

$$A n^2 C \cos^2 \alpha = L n C \cos \alpha + X C \cos \alpha + \frac{m a^2}{l} C \cos^2 \alpha;$$

$$A n^4 \cos^2 \alpha = L n^3 \cos \alpha + X n^2 \cos \alpha + \frac{m}{l}.$$

When *d* is small cos α is equal to unity, so that the discrepancy between Sir George Greenhill's equation and mine disappears:

$$A n^4 - L n^3 - X n^2 - \frac{m}{l} = 0.$$

the same as equation (7), page 387.

A more important objection to this part of the article is that, as explained above, a rotating shaft will not (under the usual assumptions) turn round the centre line through the bearings, but round its neutral fibre. So even if the calculation in itself were correct, it would not reveal what really happens, but it would only indicate for which special relations between the constants a helical form of the neutral fibre would be possible, provided the shaft could be made to turn round the bearings centre line. It may be of interest to give the result of actual calculation of the above formula for a few practical instances. For the above-mentioned factory shaft at 200 r.p.m. we find:

$$m \text{ (lb./inch) } \pi/4.\ 4.\ 0{\cdot}283\ l \text{ (in inches)} = \frac{35500}{200^2}.$$

Inserting these values and the already-determined A and L, we get:

$$2{\cdot}35.\ 10^4\ n^4 - 6{\cdot}3.\ 10^3.\ n^3 - 1 = 0.$$

This equation has the positive root $n = 0{\cdot}0143$ giving

$$\frac{2\pi}{n} = 0{\cdot}0173$$

For bearings allowing some play

$$D = \frac{\lambda}{2} = \frac{\pi}{0{\cdot}0173} \simeq 220$$

inches, an entirely possible distance.

So, in fact, the helical form of the neutral fibre would be *possible*, but, as pointed out above, the shaft has no *tendency* to take this form or to rotate at all round the bearings centre line. Moreover, even if a suitable external disturbing force did cause the shaft to "spring," for the helix to appear, it would not be sufficient that the bearings are *at least* so far apart as the calculated D, but they must be exactly *at* the right distance. If they are sensibly nearer together or farther apart, the calculated helix is not at all possible. Of course, in the neighbourhood of the calculated D, there might still appear a slightly deformed helix. So I do not think Sir George Greenhill's statement on page 274, last column, is right, where he says that: "With bearings farther apart the shaft would lose the straight line and twist up into a helix."

Another practical illustration is the propeller shaft. Supposing the diameter to be 10 in., horse power transmitted 5,000 at 500 r.p.m., and the thrust to be 40,000 lb., we find:

$$A = 30.\ 10^6.\ \frac{\pi}{64}.\ 10^4 = 1{\cdot}47.\ 10^{10},$$

$$L = \frac{5000.\ 33000.\ 12}{500.\ 2\pi} = 6{\cdot}1,\ 10^5,$$

$$X = 40000 = 4.\ 10^4,$$

$$m = \frac{\pi}{4},\ 10^3,\ 0.283 = 22{\cdot}3$$

$$l = \frac{35500}{500^2} = 0{\cdot}142$$

giving

$$1{\cdot}47.\ 10^{10}\ n^4 - 6{\cdot}1,\ 10^5\ n^3 - 4.\ 10^4.\ n^2 - 158 = 0.$$

A positive root is $N = 0{\cdot}0102$, giving $D = 306$ in. For the same power, speed and thrust, a 8-in. shaft would give $D = 273$ in.

Of course, the same remarks, as made above, hold good for these shafts. If there is *no* external disturbing force of the right frequency and direction, the shaft's neutral fibre does not rotate. If there *is* an external force (an imperfectly balanced pulley, &c.) the whole motion is different from the one examined by Sir George Greenhill, and the "critical" value of the speed (or bearings distance) depends on entirely different factors.

Yours faithfully,

Hengelo, Holland. D. DRESDEN.

* There are influences (negligible in most cases) which may make the two motions *disturb* each other, but on the usual assumptions they are mutually independent, and at all events the equation $N_1^2 + N_2^2 = N^2$ is not justified.

CIVIL AERIAL TRANSPORT.

TO THE EDITOR OF ENGINEERING.

SIR,—One's heart must go out in pity to Sir George Greenhill for the "apology" Mr. Wolff, in your issue of the 28th ult., has thrust upon him. The letter is certainly far beneath the notice of Sir George Greenhill and his critic, but as the former is disparaged and the latter is "crimed," out of fairness to both I hope you will allow me the space to administer the rebuke Mr. Wolff has merited.

Surely it should be obvious to the meanest intelligence that the plea Mr. Glauert put forward was but a quibble. His point was, I think, that no natural phenomenon is a "practical justification" of a scientific law. (A reading on this head of Professor Karl Pearson's "Grammar of Science" or Poincaré's "Science et Hypothise" should perform the operation Mr. Wolff seems to require.) Mr. Glauert was merely poking fun at the clumsy expression "practical justification," and the plea *was* for "old dame Nature" and *not* for the Newtonian theory as your correspondent affirms.

Further, Mr. Wolff carefully misreads Mr. Glauert's letter and accuses him of making an assumption—which Mr. Glauert pointed out was an impossible one—but which is the very assumption upon which Sir George Greenhill's work is based.

"But when this is taken into account . . ." (the word "this" referring to changed conditions of weight) all we have to do, it appears, is to work out the range on the false assumption that weight, speed, altitude and attitude are constant, obtaining the value

$$L = \frac{330\ n\ P}{2\ W\ .\ p}$$

and then multiply by $\frac{W}{W - P}$, thus arriving at the "true":

$$L = \frac{330\ n\ P}{2\ (W - P)\ .\ p}$$

This last value is what we should have obtained by taking W − P as the initial weight, not W, and still working on the false assumption—it may give a good approximation to L, but if it does, the accuracy can only be accidental.

With regard to the next point raised, 13½ for 13/2 is obviously a clerical error on the part of Sir George Greenhill—I have searched the article anew for a statement or even hint that W was to be taken such an average value as Mr. Wolff states—in the other example given of a flying machine to bomb Berlin the weight is taken as that stated, 15 tons, and not five-sixths as your correspondent would have him do. Further, Sir George Greenhill expressly states that "the effect of gradual consumption of petrol has not been considered." Mr. Wolff therefore tries to make it appear that Sir George Greenhill flatly contradicts himself.

With respect to the air-density controversy, Mr. Wolff has again misread the Air Board official figures, based on the values given by Mr. W. H. Dines, F.R.S., from a long series of actual observations: this distinguished authority gives the mean density in kilogrammes per cubic metre as 1·253 at sea-level, and 0·658 at 19·690 ft., so the density is not halved until a height greater than 20,000 ft. is attained. This must settle the argument. Sir George

Greenhill was probably speaking roughly without referring to actual figures.

Yours faithfully,
A. ZAIMAN.

King's College, Cambridge, March 6, 1919.

To the Editor of Engineering.

SIR,—In his letter on this subject in your issue of the 28th ult., Mr. Wolff writes as follows:—

"Mr. Glauert states that the air density is not halved until a height of greater than 20,000 ft. is attained. The Air Board tables give 18,800 ft., and Sir George Greenhill says between 15,000 ft. and 20,000 ft. I must say that I prefer the two latter authorities, in spite of Mr. Glauert's dogmatic assertion."

According to the figures used in all official performance tests carried out under the Air Ministry, the air density is halved at 21,000 ft., standard height (22,400 ft. aneroid reading). May the value of Mr. Wolff's criticism be gauged by the accuracy with which he quotes official information?

Yours faithfully,
H. A. WEBB.

Blackwater, Hants., March 7, 1919.

THE EDUCATION OF ENGINEERS.

To the Editor of Engineering.

SIR,—As a small supplement to Colonel O'Meara's recent extremely important paper "The Functions of the Engineer, his Education and Training," read before the Institution of Electrical Engineers, perhaps I can usefully call attention to the fact that amongst other counteracting advantages the war has certainly aroused parents to the desirability of a changed educational curriculum at our public schools, as well as at Oxford and Cambridge.

Soon after hostilities set in there occurred, it will be remembered, a general discussion in the Press on the subject, with the result that a committee was formed which had for its special object a reformed public school education. I became a member of this committee, of which Lord Desborough was chairman.

The first step taken was to apply to all the parents of the leading public schools (27 in all) inquiring whether they would favour a fuller education in science and modern languages, even though involving a smaller amount of time being spent on Greek and Latin. As the largest and perhaps the most conservative school, Eton may be usefully quoted as an example. Out of some 900 parents circularised, 536 replies were received, of which 512 favoured such a change; 12 were against, and 12 neutral. In other instances the result was still more striking.

The next step taken was to form a deputation to attend at the Headmasters' Association of that year. The deputation was exceedingly well received, and seems already to have had some effect at several of the public schools.

Whilst a firm believer in the public school as the best means of forming character—for which the allied forces have much to be thankful—I cannot help thinking that most of what Colonel O'Meara so ably pleads for will be more readily brought about with the changed school curriculum that I refer to.

I would like further warmly to endorse some of Mr. Highfield's remarks in the discussion relative to the great improvement effected in many of the younger generation by their experiences at the front. Many have undoubtedly become for the first time competent to manage men effectively, and this is really one of the most important characteristics of a successful engineer. Having sometimes to select candidates for important positions in Australia, I am usually struck with the small proportion who are embued with any such capacities as compared with those eminently efficient technically.

I am, &c.,
CHARLES BRIGHT.

The Athenæum, March 11.

THE POSITION OF THE OFFICIAL IN ENGINEERING WORKS.

To the Editor of Engineering.

SIR,—In his letter, published on page 176 of your issue of February 7, "Ex-Official" asks the question: "What should be done?" Presumably what should be done to raise the status and further the interests of members of the engineering profession.

It is obvious that any body formed for this purpose must necessarily be a trades union, and in spite of past failures there does not seem to be any good and valid reason why engineers should not be able to combine successfully to form a powerful association for the maintenance and advancement of their own interests. Nor does there seem to be any reason why such a body of educated men should not, by their comtined efforts, attain the same objects as have been attained by other bodies of educated men—notably those engaged in the practice of law and medicine.

It is true that at present there is in the engineering profession no fixed standard of training and attainment short of which a man ceases to be recognised as a qualified engineer, but at one time the medical and legal professions were in the same unorganised and chaotic state, and their members laboured under the same disadvantages that engineers find so detrimental at the present day. Is it not possible for engineers to follow in the footsteps of these two organised bodies? It seems to me that if they started on a sufficiently broad and democratic basis, instead of wasting time and energy in fruitless efforts to form and bolster up small associations with purely sectional interests, success would be assured. The formation of small bodies to advance the interests of small sections of the engineering profession, such as have been attempted in the past, is a movement foredoomed to failure under present conditions.

All professional engineers, whether civil, mechanical or electrical, have a common interest in the advancement of their social and professional status, and there does not seem to be any good reason why they should not all combine for that purpose. Such a combination would be unassailable in its strength and quite capable of advancing the sectional, as well as the common interests of engineers in general. Medical men, for instance, have not wasted their energies in an attempt to form separate and independent associations for those who specialise in the different branches of medicine and surgery.

The rearrangement of works on the lines suggested by ex-official is one that seems fairly certain to be effected in the near future, as far as capital and manual labour are concerned, but there is reason to fear that unless staff engineers and officials are in a position to take united action at the proper time, they will only appear in the scheme as the "trusty lieutenants" of their employers, or a small and insignificant section of the workers; that is by the sufferance of one or the other of two highly-organised and powerful bodies, for it is not conceivable that such councils or directorates could be carried on successfully without them.

Employers and manual workers are both formed into powerful federations, and unless staff engineers and officials throw aside their individualistic tendencies and take combined action they are likely to suffer sore attrition between these upper and nether millstones. It is not possible for any engineer, no matter how experienced or gifted, to stand individually against a powerful confederation of employers, and the sooner this is generally realised the better it will be for the profession.

Yours truly,
"VERITAS."

"ETHER AND MATTER."

To the Editor of Engineering.

SIR,—In thanking your reporter for his, on the whole, excellent account of my Friday evening discourse at the Royal Institution, contained in your issue of March 7, permit me to make a correction, since it involves a common but fundamental elementary error: *Page* 315, *column* 1, in the sentence "nothing is at rest *unless under the influence of balancing forces*," the qualifying clause should be omitted. Balanced forces have nothing to do with it. A body under balanced forces obeys the first law of motion, and moves solely by its own inertia, like a steady-going train or ship.

As I am writing, may I make a few other small emendations: *In the middle of column* 2, "Mr. Hope, a shipbuilder," ought to be *Mr. George Holt, a Liverpool shipowner. At the end of that paragraph*, the words "the electric theory of cohesion" require for explanation the addition—"that is, the Fitzgerald-Lorentz contraction." In the last complete paragraph of the third column, at the end, the words "collided with thousands of atoms" ought to be *passed through* thousands (or tens of thousands of atoms.

Page 316, the words "not transversal" after "radiations," should be omitted. And Sir Joseph Larmor is not responsible for the modified radiation theory which I was trying tentatively to suggest. Lower down, the words "or repeated many times" should be omitted, since the kind of stable equilibrium possessed by a brick on end is not affected by any force less than a certain critical value, however many times it is repeated. A *quantum* of energy is required to upset it; and that was the point of my very elementary illustration.

The same thing might apply, however, to a rocking portion of a sphere, which *would* accumulate the impulse of properly-timed forces until a catastrophe was precipitated—and this I conceive to be an illustration of excited radioactivity.

Yours faithfully,
OLIVER LODGE.

Mariemont, Edgbaston, March 11, 1919.

THE ACCURACY OF THE VENTURI TUBE.

To the Editor of Engineering.

SIR,—I note in the report of Messrs. Barclay and Smith's paper on "The Determination of the Efficiency of Turbo-Alternators," which appears in your issue of the 7th inst., page 322, that the authors state that the accuracy of the Venturi tube is very dependent upon up-stream conditions. This is not so unless extreme accuracy is required. I have found that even with very bad up-stream conditions the accuracy of the Venturi tube is seldom impaired by as much as 5 per cent. If a Venturi tube had been used after the flow had been steadied as shown at A in Fig. 4 of Messrs. Barclay and Smith's paper, very exact results would have been obtained. Or a simple plate orifice might have been used with equal accuracy. By either of these methods instantaneous readings of the flow could have been taken, and the very laborious, and by no means highly accurate method of the anemometer traverse avoided.

Two sensitive manometers are also mentioned in Messrs. Barclay and Smith's paper, both of which require considerable skill to use, and on neither of which a reading can be quickly taken. A manometer which I have designed for use in connection with Pitot tubes for measuring air or gas flows, or Venturi tubes or orifices across which only a small differential pressure can be allowed, and which requires no skill to use, and by means of which instantaneous readings of the flow can be taken, consists of a reservoir and a gauge tube which is so curved that equal increments in the velocity of the fluid to be measured correspond to equal distances along the scale. Manometers of this type can be constructed so that they clearly show a variation in the differential pressure of one-hundredth of a millimetre of oil at the lowest flows. These manometers can be obtained from Messrs. George Kent, Limited, of Luton, who specialise in apparatus for the commercial measurement of air, gas and steam.

Yours faithfully,
JOHN L. HODGSON.

Eggington House, Beds., March 11, 1919.

SITUATIONS VACANT.

To the Editor of Engineering.

SIR,—Allow me to ask the favour of a little space in your valuable columns, to call attention to a grievance which has existed for a long time, and which possibly you might help in suppressing. I refer to the "Situations Vacant" columns. I have been studying these of late very carefully, as I am anxious to obtain a good civil engineering appointment. I must say, however, that these advertisements are not in *many* cases properly written, because it is most unfair to state the requirements in detail, and then to add "*State salary required*" or "*Salary expected*."

Advertisements such as these are not worth considering for a moment, as the applicant has to think twice before answering them, owing to the fact that he cannot get the least inkling of whether he is in the running for 250*l.* per annum or 500*l.* per annum. In all probability, the party desiring an engineer, or draughtsman, will take the man who offers his services at the cheapest rate.

At this time especially, when we, who are eligible for demobilisation, are looking for situations, this disagreeable pill seemingly has to be swallowed, and thus causes a great deal of waste of time and paper. Firms who are not in a position to publish salaries are, I consider, open to the suspicion of being "hard-up": several of my friends are also of this opinion.

Yours truly,
G. R. R.

APPLICANTS FOR SITUATIONS.

To the Editor of Engineering.

SIR,—I read "Fed Up's" letter in last week's ENGINEERING, and sympathise with him. I was demobilised early last January, and since then I have applied for about two dozen vacancies advertised in ENGINEERING. I have spent several hours writing out these applications and copies of references, and, although fully qualified and experienced in the class of work they wanted a man for, not one single firm has had the common decency to inform me that the vacancy has been filled, not even by a small advertisement in your paper. Why are they afraid to let people know that they advertised for a man? Surely, once they let applicants know the vacancy is filled the matter is finished with. I think the least employers could do is to let demobilised men (who have answered an advertisement) know by post that the vacancy has been filled.

Yours truly,
"A TRUE PATRIOT."

March 8, 1919.

THE EFFECT OF THE EXCESS PROFITS TAX.

To the Editor of Engineering.

SIR,—May I draw the attention of the engineering world, through your columns, to what is apparently about to become a national engineering calamity.

I refer to the present stagnation of industrial and constructional work due to the slow action of our Government in not removing the present legislation in connection with excess profits. Under present conditions manufacturing concerns will not consider any sort of expansion, the result being unemployment, and, what is still worse, the loss of competent engineers who cannot afford to wait the pleasure of the "Whitehall powers," and are readily accepting the offer of other countries who "get a move on."

Yours faithfully,
H. LAWSON BROWN.

90, Princes-street, Edinburgh, March 10, 1919.

THE LONDON IRON AND STEEL EXCHANGE, LIMITED.—We are informed that although the Exchange will be open for the transaction of business on each Tuesday from 1.30 to 4 o'clock, yet "High 'Change" will be from 2.30 to 3.30 o'clock. Inquiries from buyers will be posted on the notice board in the Exchange each week. Applications for membership must be proposed and seconded by members of the Exchange.

WHITAKER'S ALMANACK.—A copy of this valuable publication for the current year (the fifty-first annual issue), has recently come to hand. Fortunately, the nature of its contents is too well known to need much explanation, as merely to mention the main headings into which its vast store of information is divided would occupy more space than we have to spare. To put the matter as briefly as possible we may say that the volume gives an account of astronomical and other natural phenomena, and also includes information and statistics of the Government, population, finances and commerce of all countries of the world. Special attention is, of course, given to the British Empire and the concluding section of the volume consists of a series of specially contributed short articles upon various products of the Empire and goods manufactured by representative British firms. The price of the volume, which contains over 1,000 pages is 6*s.*, and it is published at 12, Warwick-lane, London, E.C. 4.

THE HARDENING OF STEEL.*

By Professor H. C. H. CARPENTER, F.R.S. (Royal School of Mines).

THE capacity of steel for hardening by being quenched from a bright red heat in water, is the most important property possessed by any metallic substance. This property is utilised practically in the arts in a great variety of ways, and is the basis of all modern engineering work. To take two types of application only :—

1. The razor, the balance spring of the chronometer, and the armour plate are instances of the utilisation of this property in the finished steel, and they depend upon the capacity of such material to retain its hardness in the absence of stress, indefinitely at the ordinary temperatures.

2. More frequently, however, the property is utilised in the great variety of tools which are employed in modern engineering work, for machining metals and alloys to a high degree of accuracy, so that they may constitute a given part of one of the thousand and one machines employed in the mechanic arts of modern civilisation, *e.g.*, the locomotive, turbine, gas engine, electric motor, &c.

Not only, however, is this property of the greatest practical import, but of the highest scientific interest, inasmuch as the search for the explanation of the capacity of steel for hardening has given rise to a large number of scientific investigations, which have done more than anything else to throw light on the constitution of steels and metallic alloys generally, and have helped to establish the modern science of metallography.

My object this evening is to trace rapidly the history of some of the salient features of this scientific work and to bring to your notice the most modern views as to the scientific explanation of this wonderful property of steel.

I must preface my remarks, however, with this warning —that within the compass of an hour's lecture, it is not possible to attempt a complete exposition of the theories relating to the great variety of steel alloys that are now used in the arts, and I shall be obliged to confine my thesis to one of the simplest, albeit the best known of these materials, namely, what is called the pure carbon steel turning tool.

Let us begin by considering the manufacture of the tool itself, and afterwards the conditions under which it is put to work, and what follows then.

Although even the purest iron containing only the merest trace of carbon can be hardened to some extent by quenching from a high temperature, a certain minimum percentage of carbon is necessary before the hardening is sufficiently marked to confer what may be called practical hardening properties on the steel. This minimum is about 0·7 per cent., and the cutting tools used in the arts range from this figure up to 1·5 per cent. For reasons which will be subsequently apparent, it is simplest to consider the case of a steel tool containing 0·9 per cent. carbon. The operation of manufacture of such a tool is briefly as follows: In the first place, a charge designed to give the correct composition is melted down in a crucible in a furnace whose temperature ranges from 1,500 deg. to 1,600 deg. C. The steel is cast from the correct temperature into a metallic mould giving what is called an ingot, *e.g.*, a rectangular bar about 2½ in. square and 2 ft. long. The ingot is subsequently forged down to a bar, say, 1¼ in. to 1 in. in diameter; it is then cut up into lengths suitable for the dimensions of the tool itself; and next, it passes to the hands of the smith who forges it by hand, and fashions the tool to shape; during this operation it is of the greatest importance that the composition of the steel should be altered as little as possible by oxidation of the carbon, otherwise the tool will not harden properly or evenly; then follows the actual hardening operation, in which the nose of the tool, as it is called, is carefully heated to a given temperature in the neighbourhood of 800 deg. C., withdrawn either from the smith's fire, or, better still, the hardening bath, and quenched outright in a bath of cold water at the ordinary temperature.

This is an operation requiring the utmost skill. If the surface of the metal has been decarbonised in heating and scale has formed on the surface, the rapid transference of heat from the metal to the bath will not take place, imperfect hardening will result, and very likely cracks will be formed. If, however, the tool, as in the best modern practice, is heated up in a bath of fused salts, no loss of carbon takes place, and when it is removed from the bath, it is covered with a thin film of fused salt; this dissolves almost instantaneously in the water, and the necessary rapid transference of heat from the metal to the water takes place. The best quenchings always have a peculiar "bite," accompanied by a dull, albeit sharp, sound as the large bubbles of steam generated by the heat are absorbed in the surrounding water.

The steel thus hardened, although possessing the necessary hardness, is too brittle to be used as a tool; accordingly the tempering process follows, in which it is heated to a moderate temperature depending on the work to which it is to be put; this temperature varies usually from 200 deg. to 300 deg. C. This tempering process, while it withdraws some of the hardness produced by quenching, confers a most valuable property on the tool, namely, toughness, by means of which it stands up to its work, at any rate for a time, without cracking. Then comes the last stage, namely, the grinding of the tool on the grindstone, whereby a clean cutting edge of the required shape is produced; the tool is then ready for use.

Let us suppose that it is to be used in taking a cut from a cylindrical bar of an unhardened steel; the latter is fixed in a lathe and rotated at an appropriate speed; the tool, held in a tool-holder, actuated by suitable mechanism, is gradually brought up to the end of the rotating bar and a given rate of feed maintained; for an instant there is actual contact between the cutting edge of the tool and the bar; the moment, however, that this happens, a chip is formed, and a shearing stress is set up, as a result of which the work falls not on the actual edge of the tool, but on an area inside (Fig. 1); if the metal which is being machined is ductile, it is cut away in long shavings whose thickness depends on the feed; if, on the other hand, it is brittle, it breaks off into short chips. The effect of this friction between the two metals, and the pressure of the shaving, is to generate heat and to raise the temperature of the tool to a much greater extent than that of the bar which is being machined, and deterioration of the tool sets in; its hardness gradually diminishes, and *pari passu*, wear of the tool itself by abrasion occurs. Eventually a stage is reached at which the cutting operation has to be discontinued and the tool requires re-hardening or re-grinding. The carbon tool of which I have just spoken

Fig. 1.

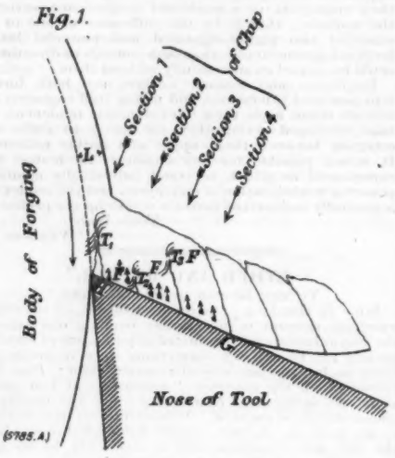
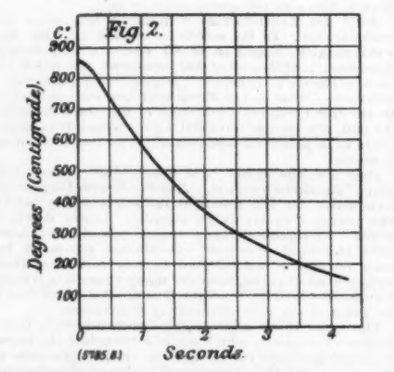


Fig. 2.



cannot be used for taking the heavy cuts of which the modern alloy tools are capable, but they retain their pre-eminence even to-day in all machinery work where the highest degree of accuracy attainable is desired.

A complete theory of the action of such tools must account for both the hardening and toughening of the steel, and its gradual loss of these properties, by the operations I have described.

Before attempting this, however, it may be interesting to refer briefly to the methods of hardening which chiefly occupied the attention of early workers.

The Greek alchemical manuscripts give various recipes from which it is clear that in the early days, the nature of the quenching liquid was considered to be all-important. There were certain rivers, the waters of which were supposed to be specially efficacious, and Pliny mentions that the difference between waters of various rivers can be recognised by workers in steel. Many old recipes for hardening and tempering have been lost, but a number of them have come down through the ages, and from them I take the following illustrations: The first is from a work entitled "Rechtegebrauch und Alchimei," 1531, of which an English translation appeared in 1583. "Take snayles and first-drawn water of a red die, of which water being taken in the first two months of harvest when it raynes, boil it with the snayles, then heate your iron red hot and quench it therein, and it shall be as hard as steele." "Ye may do the like with the blood of a man of XXX years of age and of a sanguine complexion, being of a merry nature and pleasant, . . . distilled in the middst of May." It would be interesting to know the circumstances which led up to this particular experiment being first tried. These instructions may seem trivial, but the belief in the efficacy of such solutions has continued, for in a work published in 1810* the artist is directed to take the root of blue lilies, infuse it in wine and quench the steel in it and the steel will be hard. On the other hand, he is told, that if he takes the juice or water of common beans and quenches iron or steel in it, it will be soft as lead. When the practice of an art is purely empirical, it is liable to take fantastic forms; even at the present day, however, there are many workshops where steel is hardened in which some quaint nostrum still holds sway. Occasionally, but not often, the use of these compounded baths was supported by theoretical views. Otto Tachen, for instance, writing of steel about the year 1866, says that steel "when it is quenched in water acquires strength because the light alcaly in the water is a true comforter of the light acid in the iron, and cutlers do strengthen it with alcaly of animals"—hence the use of snails.

Though the practice and theories in the periods I have mentioned were frequently fantastic, these early workers were quite right in attaching importance to the liquid in which the steel was to be quenched. To-day, much simpler methods are used in the best modern practice; if severe quenching is required, cold water or brine is used; if a lesser degree of hardening is necessary, hot water or oil, while in many cases the processes of hardening and tempering are combined in one operation by plunging the tool in a bath of molten metal such as lead.

The rapid changes of temperature which occur when a bar of steel is quenched in a liquid from a high temperature, have been studied experimentally by Le Chatelier, Benedicks and Lejeune, and their results utilised by McCance in calculating the theoretical curve of quenching. Le Chatelier found that water gave a more rapid rate of cooling than any other liquid, and concluded that the most important property in determining the quenching power of a liquid was its specific heat. Benedicks, by means of an automatic quenching and photographically recording apparatus, obtained the most accurate results which are available as to the temperature at the centre of small round bars quenched in water. On the whole his conclusions corroborated those of Le Chatelier, but he showed that the latent heat is the most important property in determining the quenching power of a liquid under practical conditions.

The annexed cooling curve (Fig. 2), deduced by McCance from Benedicks' results, shows what happened when a bar of steel containing 1 per cent. carbon, 2 in. long and ¼ in. in diameter, was quenched from 850 deg. C. in water at 15 deg. C. This curve gives the temperature at the centre of the bar at any given moment. It will be observed that it does not fall for the first fraction of a second; that the rate of fall starts slowly, then increases rapidly to a maximum, afterwards decreasing more and more slowly until it reaches the temperature of the surrounding water. From our present point of view the important thing to notice is, that the time from the moment of immersion until the temperature had dropped to 500 deg. C. was 1½ seconds. As the diameter of the bar increases, the rate of chilling is, of course, diminished, and no doubt in the case of a rectangular turning tool of 1½ in. diameter, several seconds would be required for the same drop in temperature at the centre. As McCance has pointed out, the perfect theoretical conditions for quenching are "that a specimen heated uniformly has its surface suddenly cooled to a lower temperature and kept at that lower temperature without alteration, until it has once more obtained uniformity, but at the lower temperature; the temperature of the bar changes then in a manner depending on its thermal properties and dimensions, and the rate of change thus obtained cannot be exceeded between similar temperature limits. Practical quenching depends on how far these conditions are satisfied, which really resolves itself into the simple question, how constant can the surface of the specimen be kept at the lower temperature after immersion in the liquid, and what properties must the liquid possess to fulfil this purpose best." McCance accepts Benedicks' conclusion that vaporisation plays the most important part in the quenching power of a liquid, and the fact that water, with its high latent heat of vaporisation, is the best quenching liquid known accords with this view.

What happens when a uniformly-heated bar is plunged into water at 0 deg. C. is somewhat as follows: The layers of water in immediate contact with the bar are rapidly heated to their boiling-point and steam is formed; this expands outward and causes a fresh layer to come in contact with the surface, and so the process goes on; the surface of the bar alternates then between 0 deg. C. and 100 deg. C., the steam acting as a carrier of heat to the body of the liquid; this goes on until the supply of heat is insufficient to form steam, when the transference of heat and the cooling of the bar take place by convection only; and at this stage of the process a high conductivity in the liquid is an actual disadvantage, since it retards convection. A low viscosity is wanted to enable the steam to travel outwards with as little resistance as possible, while a high specific heat ensures that the temperature changes of the liquid are small.

We have next to consider certain fundamental properties of iron and its alloys with carbon which have been established by modern research, and without a knowledge of which any discussion of theories of hardening would be unintelligible. These properties have been for the most part investigated during the last fifty years by a small band of devoted research workers who have been the pioneers in founding the modern science of metallography.

The application of the microscope to the study of the constitution of iron and steel, regarding these materials as igneous rocks, is due to Henry Clifton Sorby, of Sheffield, who died only a few years ago, while the use of the thermo-electric pyrometer as a means of studying the changes of internal energy in the same materials is

* Discourse delivered at the Royal Institution, on Friday, March 7, 1919.

* The Laboratory or School of Arts.

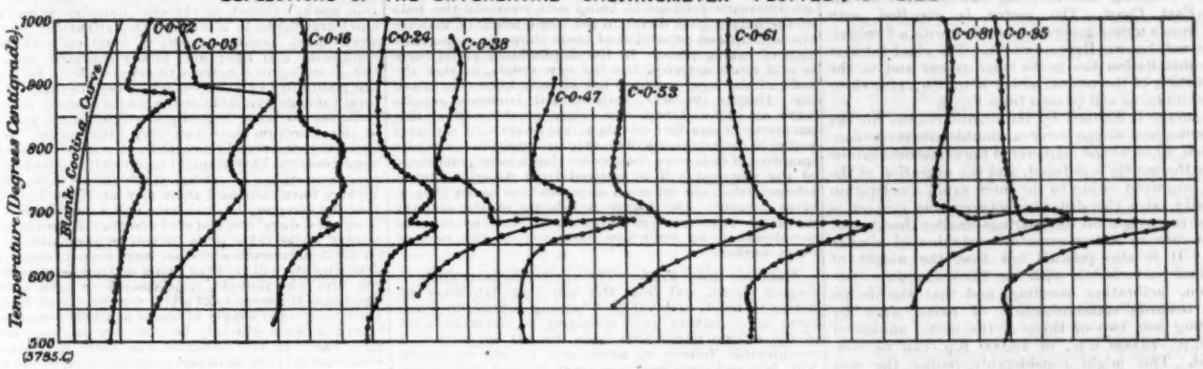
the work of a Frenchman who is still living—M. Henri le Chatelier. The methods opened up by these pioneers have proved extremely fruitful, and the results achieved by their systematic exploitation have brought certainty into a field where previously only speculation reigned. With these results it is necessary to deal briefly.

in magnitude; finally, at about 0·9 per cent. carbon, all three points coincide at one temperature, namely, that of the Ar_1 change about 700 deg. C. It is obvious from the foregoing that while the points Ar_3 and Ar_2 are characteristic of iron, the point Ar_1 is characteristic of iron plus carbon, namely, steel.

has been chosen for illustrating the theories of hardening. Such a steel, when cooled from a high temperature, has only the one critical point on cooling, namely, at S, and therefore furnishes the simplest case for discussion.

From a reference to the diagram, it will be clear that if a steel tool is quenched from a red heat, say, about

Fig. 3. COOLING CURVES OF IRON AND IRON-CARBON ALLOYS.
DEFLECTIONS OF THE DIFFERENTIAL GALVANOMETER PLOTTED 1/15TH SIZE.



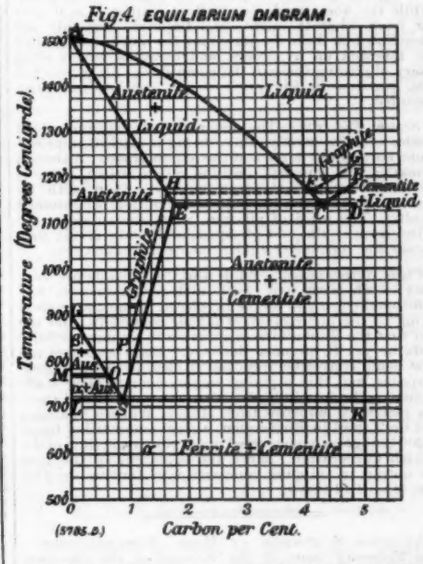
It will be convenient first to consider the evidence afforded by accurate pyrometry, although historically the microscope led the way. It is now known that the purest iron which can be obtained, containing as it does not more than three parts of impurity per 10,000, can exist in at least three different modifications, and there is every reason to believe that these modifications are a property of the iron and not in any way due to the small amount of impurities mentioned. If the cooling of a sample of such iron from the melting-point (1,505 deg. C.) is followed by means of a delicate pyrometer and potentiometer, the cooling is found to be normal for about 600 deg. At about 900 deg. C., however (Fig. 3), there is a sudden and large evolution of heat which completes itself within a few degrees, and is sufficient to arrest the fall of temperature completely for a time; after this, the cooling proceeds for an interval and then another evolution of heat occurs; this is different in character and amount from the previous one; it is markedly smaller in quantity and is spread over a considerable temperature interval, which ranges from approximately 780 deg. to 740 deg. C. In the latter case the evolution of heat is never sufficient to arrest the fall of temperature completely. Below this point there is no further abnormality in the rate of cooling to the ordinary temperature. These two heat evolutions were rightly regarded by the early workers as marking critical points in the history of the iron on cooling, and were called by their discoverer, the late M. Osmond, Ar_3 and Ar_2. From the freezing-point down to Ar_3 the iron is known as γ, between Ar_3 and Ar_2 as β, and below Ar_2 as α. These three varieties of iron have characteristic properties, of which, from the point of view of the argument of this lecture, the following should be noted: γ iron is completely non-magnetic, and has a considerable power of dissolving carbon, the amount of which varies with the temperature; it has also a characteristic crystalline form. β iron is also non-magnetic, but its capacity for dissolving carbon is almost nil, and it also has a characteristic crystalline form. α iron, on the other hand, is magnetic, but in all other respects it resembles β iron very closely, and no difference in crystalline symmetry between these two varieties has yet been discovered. A considerable controversy has raged for many years now as to whether each of these varieties is to be regarded as an allotropic form of the metal. Even now, this question is not yet settled, chiefly because there is, as yet, no consensus of opinion as to the definition of allotropy. If, however, a change in crystalline symmetry be regarded as the criterion of an allotropic change, then γ iron is certainly to be regarded as an allotrope, whereas β and α iron are to be regarded as the same variety, the only difference being that β iron is α iron which, owing to rise of temperature, has lost its magnetic properties. From the point of view of the hardening of steel, the important difference between these varieties of iron, is that γ iron can dissolve substantial amounts of carbon, whereas β and α iron cannot, and the unique position occupied by carbon as a hardening agent in steel is intimately connected with this difference in properties.

By adding carbon to iron and thus making a steel, a marked influence on the critical points of the metal is observed; taking, for example, a steel with 0·15 per cent. carbon, it is found that the temperature of the Ar_3 charge is lowered, that the Ar_2 charge is unaffected, and that a third critical point makes its appearance at about 700 deg. C., this last-named point being of small magnitude, but completed within a very narrow range of temperature. This is known as Ar_1.

Taking next an alloy with 0·35 per cent. carbon, the position of Ar_3 is still further lowered. Ar_2 still remains the same, while Ar_1 appears as a much larger point.

At about 0·45 per cent. C., Ar_3 has been so much lowered that it coincides with Ar_2, in other words at this composition γ iron changes directly to α. Ar_1 is also observed and has grown in magnitude. With the gradual addition of carbon Ar_3 and Ar_2, which have now become one point, are still further lowered, while Ar_1 increases

Fig. 4. EQUILIBRIUM DIAGRAM.



The interpretation of the critical points thus briefly outlined has been rendered possible by the combined study of the foregoing method with the microscope, which has revealed the structural changes accompanying these heat evolutions, controlled by a consideration of the requirements of the phase rule and elaborated into what is known as the iron-carbon equilibrium diagram. This diagram, whose co-ordinates are temperature and concentration, defines what, at any given temperature and concentration, are the constituents present in an iron-carbon alloy. In so far as a knowledge of these is required in connection with the hardening of steel attention may be confined to the left-hand portion of the diagram between the limits of concentration 0 per cent. to 1·5 per cent. The area A G O S E (Fig. 4) defines the limits of existence of γ iron, from which it will be seen that it can exist from 1,500 deg. to 700 deg. C. and from 0 per cent. up to 1·8 per cent. carbon. This constituent is also known as austenite. Within this area the carbon present in all steels is dissolved, and the evidence both chemical and physical indicates that it is combined with, as well as dissolved, in the iron as a carbide of iron. Below 700 deg. C. only α iron is stable, and in a normally-cooled steel almost the whole of the carbon is precipitated as a crystallized carbide of iron Fe_3C. At the point S, corresponding to the composition 0·9 per cent. carbon, we have the simplest case possible, for the austenite is resolved on cooling below it into a mixture of α iron and iron carbide Fe_3C. This mixture separates in characteristic alternate plates with a laminated appearance, and is called pearlite from its analogy to mother-of-pearl. It consists of about 86·5 per cent. iron and 13·5 per cent. Fe_3C., on the assumption that no carbide is dissolved in the iron; this assumption is not strictly speaking true, but the amount dissolved is so small that for practical purposes it may be neglected.

Steels on the left-hand side of S consist, below 700 deg. C., of a mixture of iron and pearlite, whereas those to the right of S consist of a mixture of iron, carbide and pearlite. From this diagram, it will be seen why a tool steel containing 0·9 per cent. carbon

800 deg. C., at the moment of quenching, the constituent present is austenite. The act of quenching has for its object the rapid passage of the metal through the change point S, and the prevention of the separation of the single constituent austenite into the two constituents of pearlite.

(To be continued.)

IRON PRICES.—The Minister of Munitions has given notice that the maximum prices for home sales of bar iron, marked bars, rolled edges iron strip, sheared iron tube strip and iron plates and sheets have been advanced 30*s.* per ton since the 6th inst.

COAL EXPORTS AND BUNKER COAL.—The Board of Trade have made a direction, dated the 10th inst., providing that no delivery of coal for export or for use as ships' bunkers shall, without the express consent of the Controller of Coal Mines, be made by or on behalf of the owners of any colliery in pursuance of any contract made prior to August 4, 1914.

NON-FERROUS MATERIALS.—The following particulars are published of the stocks (exclusive of old metal and scrap) in this country in possession of the Minister of Munitions on the 1st inst.:—

	Tons.
Copper	51,373
Spelter, G.O.B.	27,444
Spelter, refined	8,860
Aluminium	13,004
Soft pig lead	100,063
Nickel	2,332
Antimony, régulus	4,325

DISPOSAL OF ELECTRICAL APPARATUS.—The Disposal Board of the Ministry of Munitions has now completed its organisation for the disposal of the quantities of electrical apparatus and equipment that were manufactured to help win the war, and are now becoming available for the requirements of peace time development. The electrical material as it comes to hand for purposes of sale will be grouped under the following headings:—(A) Lighting Accessories and Fans; (B) Cables; (C) Bell Materials; (D) Electrical Instruments; (E) Telegraph Materials; (F) Telephones, C.B., and Magneto; (G) Telephones, Field and Intercommunication; (H) Wireless Apparatus; (J) Searchlights, Arc Lamps and Equipment; (K) Plant. Intending purchasers should write to the Disposal Board (Electrical Section, Caxton House, Westminster, S.W. 1) stating in which of the above headings they are interested. Advice of impending sales will be widely advertised through the Press, and notifications will also be sent direct to prospective purchasers as material becomes available.

THE BRITISH ASSOCIATION.—Old members of the British Association will be glad to learn that the meetings, interrupted since the Newcastle meeting in 1916, are to be resumed at Bournemouth this autumn. Bournemouth had invited the association for 1917, a Cardiff meeting to follow in 1918. Both these invitations were subsequently renewed for later years, and the Hon. Sir Charles Parsons, F.R.S., is to take the chair, vacated by Sir Arthur Evans, at Bournemouth, on Tuesday, September 9. It is to be a short meeting again, closing on Saturday, September 13. But war restrictions placed upon information of a confidential character will be removed, and one may thus look forward to instructive communications and discussions. The Municipal College will be placed at the disposal of the British Association. A special feature will again, as in late years, be made of citizens' lectures, not restricted to members of the association; these lectures will be arranged in conjunction with the local branch of the Workers' Educational Association, an arrangement which gave satisfaction at Newcastle.

19,000-H.P. REVERSING ROLLING-MILL MOTOR.

THE illustrations on page 344 show an interesting rolling-mill motor recently constructed at the Stafford works of Messrs. Siemens Brothers Dynamo Works, Limited. The motor, which on peak load is capable of exerting 19,000 h.p. at speeds from 60 r.p.m. to 140 r.p.m. in either direction, has been built for driving a 36-in. roughing and finishing mill situated on the North-East Coast. The motor is supplied with power from a motor-generator set fitted with a flywheel, on the well-known Ilgner system. The chief interest of the installation lies in its large power and in the construction of the motor, which is split up into three coupled units, as will be seen from Fig. 1.

Advantage is claimed by the manufacturers for the three-armature design over a double-armature construction, since, as the diameter of the armatures can be smaller the inertia is reduced, and the operation of the mill is improved owing to the more rapid acceleration obtained; also the distance between the centres is less and the weight on the bearings smaller than would be the case in a two-armature machine of similar power. It is also pointed out that the weight of individual parts is less with the three-armature construction, facilitating handling, and that the design assists towards standardisation of parts, since by employing one, two or three of the units, motors of 6,500 h.p., 13,000 h.p., or 19,000 h.p. can be constructed. This might considerably reduce the cost of spares carried in connection with a large rolling-mill installation.

Turning to the details of the motor, attention may be directed to Fig. 2, which shows one of the armatures with the core plates built up, but before the windings have been placed in position. This figure also shows the central air gap and end plates which have been designed for providing ample ventilation. The main pole pieces are provided with a similar central gap, the gaps acting as a passage-way for the forced draught ventilation and providing an efficient means of cooling at the centre of the compensating winding bars. The armatures are built up on cast-steel spiders and are provided with independent shafts. The drive is transmitted through the spiders which are connected by special coupling pieces between the units. The couplings register the spiders and provide for a drive in either direction through special keys. These coupled spiders ensure great rigidity and reduce deflection between centres to a minimum. Each armature is fitted with a double commutator. The three units, as will be seen from Fig. 1, are mounted on a combined bedplate.

As has already been said, the motor is capable of carrying a peak load of 19,000 h.p. at speeds from 60 r.p.m. to 140 r.p.m. in either direction. The pressure across the armatures is 1,400 volts, the diameter of the shaft in bearing is 24 in., and the shaft extension 27 in. The weight of the complete machine is approximately 300 tons. The motor generating set, which supplies power to the rolling-mill motor, consists of a three-phase driving motor having a continuous rating of 3,750 h.p. on a 2,750-volt, 40-period, three-phase current, and runs at 400 r.p.m. This motor is directly coupled to, and is mounted on, the same bedplate with two variable-pressure generators, with a flywheel between them. The flywheel is of the built-up type, is 15 ft. in diameter and weighs 40 tons. As the mill is entirely controlled by varying the fields of the exciters supplying respectively the fields of the variable-pressure generators, and the mill motor, the main controller is of small dimensions. The motor we illustrate recently passed its tests at the builders' works, and a similar set is now under construction for driving a 34-in. roughing and finishing mill in the Sheffield district. Messrs. Siemens also have under construction at Stafford two similar motors, of 12,000 h.p. and 6,400 h.p. respectively.

PERSONAL.—The Westinghouse Brake Company, Limited, have appointed Captain T. Barty, late of the Royal Engineers, to act as their representative with the British and foreign railway companies. Captain Barty has for some time been acting as brake engineer at the Base Locomotive Works of the British Expeditionary Force in France. He was, before the war, manager of the Steam Heating Department of the Westinghouse Brake Company, Limited, and previously was assistant to the outdoor locomotive superintendent of the Caledonian Railway.—Maj. R. Stevenson, M.C., Inspector of Ordnance Machinery, M.I.E.S., A.M.I.Mech.E., F.C.S., Extra Chief Marine Engineer, having been demobilised after service since 1914, principally overseas, together with Dr. H. V. A. Briscoe (Lond.), D.I.C., A.R.C.S.(Lond.), F.C.S., are opening offices at 34, West George-street, Glasgow, as inspecting and consulting engineers and chemical engineers.—The Brightside Foundry and Engineering Company, Limited, Heating and Ventilating Engineers, of Sheffield, London and Birmingham, have opened a West of England branch of this business at State Insurance Buildings, 14, Dale-street, Liverpool.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—In the steel trade, despite many factors of a rather untoward nature, very considerable activity prevails, and the rolling mills are kept fully employed. The existing uncertainty of labour generally, the cost of production, and the continued difficulties of transport are a decided handicap, and neither makers nor consumers display any disposition to do other than meet the most necessitous requirements. While quite an extensive tonnage is being sent overseas the bulk of the output goes direct to the home markets, and yet the anticipated expansion of trade shows no immediate sign of taking place. In the shipbuilding yards there is still much activity, but few new orders, so that the bulk of the steel required has already been contracted for. During the war, railway and tramway repairs were an impossibility, and, while much work of this nature must now be overtaken, it is doubtful if the steel works in the country will be able to supply the requisite quantity of rails—the chances are that a large percentage of the material will be ordered from America, unless labour makes the question of production easier than it is at present. The future well-being of the country demands an increase of output, and this can only be accomplished by strenuous exertions on the part of every worker.

Malleable Iron Trade.—The malleable iron trade is forging ahead, and from the fact that deliveries are better in hand, and not now lagging behind, it would seem as if makers were managing to overtake some of the arrears which have been, up till the present, a considerable source of annoyance to all concerned. Nut, bolt and rivet iron is in great demand, and so also are various sections required for home consumption. While the home trade is excellent, export is still very far from what it might be. Inquiries certainly are plentiful, but these do not count for much, unless they are followed up by orders, and overseas buyers seem chary of placing these in the meantime. An advance of 30*s.* per ton in the price of bar iron has just been recorded.

Scotch Pig-Iron.—The demand for pig-iron of all grades remains steady, there being a marked improvement both in the home and the export trade. Although hematite and foundry continue rather scarce, there is an ample supply of forge quality. Even with an expansion of export, the bulk of the output is consumed locally. The price of pig-iron, when the subsidies are withdrawn at the end of April, is already giving producers and consumers alike some cause for anxiety.

Clyde Shipbuilding.—While the Clyde yards are very busy, both with new work and reconstruction, few additional contracts are being placed meantime, mainly owing to the uncertainty of labour conditions, and the fact that the shipbuilders are unable to estimate definite costs or yet to promise delivery. Many steamers are now being converted from naval back to their original purposes, and this is giving employment to large staffs of men. The Admiralty is still in the market, and there has just been launched from Messrs. William Chalmers and Co.'s yard in Rutherglen, a steel ammunition barge of 206 tons gross, constructed under the supervision of the British Corporation. Since the beginning of the year the output of shipping compares very favourably with that of normal times.

AMMONIA SYNTHESIS AT HIGH TEMPERATURES.—The February issue of the Journal of the Chemical Society contains a further paper by Dr. E. B. Maxted on the "Synthesis of Ammonia at High Temperatures," supporting the conclusion formerly drawn that the percentage of ammonia, in equilibrium with nitrogen and hydrogen, first decreases with increasing temperatures, but increases subsequently, after passing through a minimum, when the temperature is further raised, as it should do from thermodynamical considerations. The temperatures were not determined; in the recent experiments an electric arc of 50 cycles is used, the potential of 375 volts being raised by a static transformer (oil-immersed) with a step-up factor of 31·5. The experiments are made on a small scale in an inverted glass flask. Through the stopper and neck passes a thick-walled silica capillary, up to the centre of the flask, where the capiollary is flattened out and cut so as to form a slit, 4 mm. long and 1·5 mm. wide. In this slit rest the spherical ends, beads of 1 mm. diameter, of two platinum wires which run along the tube; the beads are the arc electrodes. The gas mixture, 75 per cent. of hydrogen and 25 per cent. of nitrogen, is introduced laterally into the neck of the flask, above the stopper, and the gas is drawn off again through the silica tube, into which, therefore, the arc itself is drawn. The gas feed was varied between 0·5 litres and 2·1 litres per hour. With a slow gas flow the ammonia formed was decomposed again; rapid cooling is required. The point particularly studied by Maxted is whether traces of oxygen are necessary for the synthesis; it has been suggested that nitric oxide would first be formed and then be decomposed. All oxygen contamination was avoided, and the same gas mixture was circulated up to 16 times through the flask on the assumption that any oxygen present should display its activity more in the first reaction than in the subsequent ones. But the percentage of ammonia remained, in these continuous circulation experiments, fairly steady at 1·7 per cent., the maximum obtained was 2 per cent. Maxted considers that he thus established the direct synthesis of ammonia; that may be right, but his experiments would hardly disprove any catalytic action of the oxygen.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The feeling is general that when confidence has been restored in regard to prices, orders will flow in at a much more satisfactory rate. Meanwhile, there are signs of weakness in local manufacture, chiefly in the heavy branches. Unemployment has materially increased. Eighteen thousand workers are registered at the Sheffield Labour Exchange for unemployment benefit. There may be further additions this week. Unrest in the coal industry is one of the chief drawbacks to a more settled situation. For some weeks past, manufacturers, in common with railway companies and light and power concerns, have been endeavouring to construct reserve stocks of fuel against the possibility of a suspension in coal output. But the total tonnage available at the pits is scarcely more than sufficient to meet immediate requirements, and efforts in this direction have had very little result. While a cheerful tone prevails in regard to the immediate outlook, some concerns have thought it advisable to make a frank communication to their employees. Thus, Messrs. Vickers have informed their men at River Don Works that the company has not been able to accumulate more than a few days' stock of coal and that, if the threatened miners' strike takes place, it will be impossible to carry on the departments which are large users of coal. Other departments will be kept going as long as possible, but the firm has thought it advisable to give notice to determine the services of all its workpeople on March 22. Until the proper supply of coal is available, engagements from that date will only be from day to day. Work is still scarce in the furnaces, but there is evidence of abundant activity in departments devoted to the manufacture of railway and tramway material. The latest inquiries show the prospect of a big demand for railway steel from home and Continental users, though, from the general standpoint, foreign and colonial trade is surrounded by too many difficulties to make the cultivation of new markets and the renewal of old an easy process. Quite the busiest sections of local industry are the tool trades. There are to-day more orders for engineers' and farm tools than can be dealt with, and business is literally being turned away. Consequently the demand for tool steel is very large and makers are booked well ahead. High-speed steel is a dull market. No improvement in business has followed the release of tungsten to makers at reduced rates—rather the reverse. Makers are largely working on substantial stocks left on hand at the end of the war.

South Yorkshire Coal Trade.—Coal supplies are rather more satisfactory, but the increased output resulting from the further return of men from the Colours is mostly required to meet contract commitments, and very little remains for purchase on the open market. Quotations for all descriptions of fuel are at the full maximum rates allowed, and are mostly nominal. All kinds of steam fuel are in big demand, and inland works are taking large tonnages of gas fuels. House coal merchants have managed to work off some of their arrears, but could still deal with a larger tonnage. Slacks are fairly plentiful. Blast-furnace coke is a strong market at top rates. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

ACETYLENE CONSUMPTION IN AUTOGENOUS WELDING.—It is sometimes asserted that the acetylene consumption in autogenous welding can be decreased by increasing the pressure at which the acetylene is used. Some recent experiments made in the works of Julius Pintsch, A.G., do not confirm this belief. Comparative welds of steel plates, in lengths of 6 m., were made, ten plates being welded in each case; in the first series the acetylene pressure was 300 mm. of water, in the second series it was 4,000 mm. and sometimes 5,000 mm. of water; the oxygen pressure was not altered during the experiments. A distinct difference in the acetylene consumption was not observed. Much would, of course, depend upon the manner in which the operations are conducted. It is, however, concluded that the pressure should be kept steadily at the rate for which the burner is adjusted when equal volumes of acetylene and of oxygen would be admitted.

OCCUPATION OF BLIND MEN IN TESTING LABORATORIES.—In 1916, 50 blind men, war victims, were placed in the fireworks laboratory, part of the military munition works of Spandau, near Berlin. They were first trained by women and, later, instructed by blind men. Originally they were only given very simple test work of the "go" and "not-go" kind. The dreary monotony of this occupation proved very bad for them, however, and the scope of their work was gradually widened; they were allowed the use of files, drills and groove-cutting tools, and finally of lathes and milled cutters. Special devices had to be designed for their protection, of course; the lathe is stopped, for instance, when the tool has done its work for the time, and the piece is automatically thrown into a basket for examination by the man. Frequent changes are made in the routine work. At first the proficiency of the men was low; last year they were said to do on average from 80 per cent. to 90 per cent. of the work which able-bodied men could have done. Most of the men are married, and the wives, partly occupied in other departments of the establishment, act as their guides.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is little new to report concerning Cleveland pig-iron. Output of foundry kind is still altogether inadequate even to home needs, so that next to none can be had for shipment abroad. The scarcity is very largely due to the unsatisfactory working of blast furnaces, and the consequent proportionately small output of foundry pig-iron, and large make of inferior iron. It is reported that a couple of furnaces running on basic iron are to be transferred to the production of Cleveland pig-iron, and if this is so there may be some increase in the make of foundry quality in the near future. Meanwhile exporters are much disappointed at being unable to buy for shipment abroad, as they can now obtain licences without any difficulty. Forge iron is quite plentiful, and is selling freely, buyers taking it up to mix as extensively as possible with foundry kind. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; whilst for export, No. 3 and the lower qualities are 145*s.* and No. 1 is 150*s.*

Hematite Iron.—Satisfactory account is given of the East Coast hematite branch. A very considerable home trade is passing, and it is gratifying to know that demand for such purpose is not only fully met, but that there is a fair surplus of iron available for disposal elsewhere. Under such conditions traders are naturally seeking sanction to export what can be spared to overseas customers, but permits for such despatch are still granted very sparingly, the authorities apparently favouring the policy of conserving stocks. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use, and 172*s.* 6*d.* for export.

Foreign Ore.—Business passing in foreign ore just now is very small, but with the removal of official chartering of ore steamers renewal of activity is looked for, though it is recognised that values are stiffening. Meanwhile consumers have large stocks, and are regularly receiving good deliveries in fulfilment of running contracts.

Coke.—Coke is, if anything, less scarce. All essential local requirements are receiving adequate attention, but consumers have no stocks to speak of, and are still pressing insistently for larger deliveries. Average blast-furnace coke is 33*s.* at the ovens and low phosphorus sort 35*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—In finished iron and steel, outlook as regards fuel and labour continue to cause some anxiety, and disinclination to make heavy forward contracts at fixed prices is noticeable, but manufacturers have excellent orders booked. Inquiries are numerous and further heavy home contracts for next month would readily be given if firms would guarantee delivery, whilst foreign demand is large and extending. Of course, it is fully recognised that the approaching end of the control period so far as pig-iron is concerned, will inevitably necessitate a variation in steel prices. To home customers the following are among the principal market quotations:—Common iron bars, 17*l.* 15*s.*; steel ship, bridge and tank plates, 14*l.*; steel boiler plates, 15*l.*; chequer plates, 15*l.* 10*s.*; steel angles, 13*l.* 12*s.* 6*d.*; steel joists, 13*l.* 12*s.* 6*d.*; steel billets and blooms, 12*l.* 5*s.* to 12*l.* 15*s.*; and steel rails, 13*l.* 10*s.*; whilst export prices include: Common iron bars, 20*l.*; steel ship, bridge and tank plates, 16*l.* 10*s.*; steel boiler plates, 17*l.* 10*s.*; chequer plates, 18*l.*; steel angles, 16*l.* 2*s.* 6*d.*; steel joists, 16*l.* 2*s.* 6*d.*; billets and blooms, 13*l.* 10*s.* to 15*l.*; and steel rails, 15*l.* 10*s.*

SHIPPING FACILITIES TO THE BALTIC.—The *Hamburgischer Correspondent* for February 9 learns from Copenhagen that the scheme for constructing a large harbour at Korsör, a Danish seaport 69 miles W.S.W. of Copenhagen, is likely to be realised with the assistance of American capital. The cost is estimated at 30,000,000 kronen. The harbour will extend from the steamship berths to the Halikö Odde, and it is intended to make use of the deep water in the bay. Large quays will be constructed, with ample facilities for dealing with merchandise. The harbour is to have a depth of 10 m., as against 9 m. in Copenhagen. Should the scheme succeed, an important step will have been taken in the direction of bringing the transit trade of Northern Europe through Denmark. Discussing the Danish dream of making Copenhagen the great transport centre for the Baltic, *Svensk Export* for January declares that Denmark will not be able to dominate Scandinavian trade, and expresses the view that Sweden will become the most important economic factor among the countries on the Baltic. She is less than ever inclined to leave her foreign commerce in the hands of foreign agents, and she has taken steps to secure the advantages possessed by Copenhagen as a free port. The Swedish free harbour at Malmö will prove a dangerous rival to the Danish metropolis. Its situation is just as advantageous, being on the high road for all traffic to and from the Baltic, and the harbour, which is rapidly nearing completion, will offer the same facilities as the port of Copenhagen, with the additional advantage that it has a far larger and rich country to support it. Moreover, Sweden is absolutely adapted to be the transit country for traffic between the eastern and western parts of Northern Europe, and the free ports of Stockholm and Gothenburg, both of them termini, provide the most rapid means of communication between Western Europe and Russia, and will certainly play an important part in creating and maintaining an extensive transit trade *vis* Sweden. This will not prevent Copenhagen from also extending its share in the coming development of Baltic trade.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Coal Markets.—New business has again been on very conservative lines on the local coal markets during the past week, and until the uncertainty of the labour position is removed little change is anticipated, as both buyers and sellers are adopting a very cautious attitude and generally "marking time" pending the outcome of the deliberations of the Coal Commission Inquiry. Great interest is being taken in the proceedings of the inquiry, and the sensation caused by the estimated cost of the extra 2*s.* 6*d.* allowed on coals to the collieries has come in for much comment. The fallacy that the coal owners netted 5,000,000*l.* by the 2*s.* 6*d.* increase has been properly exploded by the facts put forward. The stoppage in the Dowlais district continues, and little hopes of an early settlement are entertained. It is now reported that the Bureau des Charbons, Paris (the French Coal Committee) are to be replaced by the Office Central des Charbons, and that coal cards are to be issued which will be given to the importer or seller; whether this change in the French system of distribution will be followed by a change in the exporting system on this side is not yet known. Transport difficulties continue materially to restrict the free export of coals, while inadequate loading facilities at the docks are also retarding export business. In many cases vessels have been waiting in dock for over a fortnight to get cargoes. The inland demand for coals shows no abatement and collieries are busy coping with the inquiry. The requirements of the authorities are also heavy, while the collieries themselves are also banking coals for their own use in the event of a stoppage in the coalfield. In the circumstances, after the requirements of allied countries are met there is little fuel left for neutrals and for these destinations few licences are being granted. Even where licences to ship have been authorised it is very difficult to get the coals released. Large steam and dry coals are very scarce, and the same applies to bunker and the best descriptions of small steams. Inferior steam and dry smalls continue plentiful and without much demand. Coke makers are experiencing difficulty in getting rid of their outputs owing to a scarcity of allocated tonnage, and in many instances they have been obliged to ease down outputs. The subsidy granted to coke manufacturers is to be abolished at the end of the month, and makers consider the position serious. Patent fuel exports are slow, but makers have sufficient orders to keep them going a fortnight or more.

The Newport Market.—On paper collieries are fully stemmed, but the difficulty is to get coals released by the authorities. The demand is able to absorb outputs, but business is restricted to the capacity of transport. In several instances collieries have had to effect temporary stoppages owing to a scarcity of empty wagons, while in other cases coals are held up at the docks waiting release. Best Monmouthshire large coals are difficult to secure, as also are superior smalls, but the cheaper smalls remain more than sufficient to meet buyers' requirements.

Swansea's General Trade Prospects.—At the annual meeting of the Swansea Harbour Trustees this week it was stated that the outlook of the general cargo trade was even more promising than had been anticipated. The Royal Mail Steam Packet Company is about to resume its service to the port and will be sending one of its large steamers early next month, as also were the Holt line. Mr. Roger Beck was re-elected chairman of the Trust.

The Release of Shipping.—Mr. Lewis Lougher, managing owner of the Redcroft Steam Navigation Company, Limited, who has been elected chairman of the Cardiff and Bristol Channel Shipowners' Association, in his presidential address said that the work of the association during the year would be largely concerned with the problems arising from the period of reconstruction. The effect of the release of tonnage had been clearly demonstrated, as the current free freight rates were very considerably below those which were ruling during the war. In future foreign competition would be greater than ever, but he had every confidence that British shipping, divested of the shackles of State control, would prosper, and that shipowners by their indefatigable energy and enterprise would not rest until they had regained the maritime supremacy which this country had held for many years.

Newport Shell Factory.—The machinery and plant, including many makes of machine tools in good condition, of the Newport National Shell Factory, is being disposed of by the authorities.

OBERHOFFER'S ETCHING REAGENT FOR STEEL.—In 1916 Oberhoffer proposed a modification of Stead's steel reagent for the detection of phosphorus. In steels containing not more than 0·9 per cent. of carbon this reagent readily allows of distinguishing between areas rich and poor in phosphorus. The micrographs obtained look, as Bauer stated some time ago, like negatives of specimens etched with copper-ammonium chloride. This statement is confirmed by K. Harnecker and E. Rassow, of Tegel, near Berlin, in *Stahl und Eisen* of November 21, 1918. Etched with Oberhoffer's reagent the low-phosphorus dendrites of a steel casting look dark on the background of the higher-phosphorus area, when the illumination is vertical, with oblique illumination the appearance is reversed. The high-phosphorus areas form a perfect negative of the same section when etched with copper-ammonium chloride, the illumination being vertical in both cases.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 14, at 7.30 p.m., at 39, Victoria-street, Westminster, S.W. Paper by Mr. Ernest Hooper (Member), "A History of the Locomotive."

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.—Saturday, March 15, at the Institute, Wolverhampton-street, Dudley, when a discussion on Mr. Carrington's paper on "Gas Furnaces," read on February 2, 1918, will be continued. Chair to be taken at 6.30 p.m.

THE INSTITUTION OF SANITARY ENGINEERS.—Monday, March 17, at Caxton Hall, Caxton-street, Westminster, S.W., when a Sessional Meeting will be held. Subject: "Sewage Disposal by Dilution; including Chlorination of Sewage Effluent and Treatment of Sludge," by Mr. W. C. Easdale (Fellow). Major T. J. Moss-Flower (president) will take the chair at 7.30 p.m.

THE ROYAL SOCIETY OF ARTS.—Monday, March 17, at 4.30 p.m., Cantor Lecture: "Coal and its Conservation," by Mr. William Arthur Bone, D.Sc., Ph.D., F.R.S., Professor of Chemical Technology (Fuel and Refractory Materials), Imperial College of Science and Technology. (Lecture II.) Wednesday, March 19, at 4.30 p.m., Ordinary Meeting: "The Distribution of Heat, Light and Motive Power by Gas and Electricity," By Sir Dugald Clerk, K.B.E., D.Sc., F.R.S. The Right Hon. Lord Moulton, G.B.E., K.C.B., LL.D., F.R.S., will preside.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, March 18, at 5.30 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. The following paper will be read: "Plant Employed in the Percussion Systems of Drilling Oil Wells," by Mr. Maurice A. Ockenden, M.I.Mech.E., F.G.S., and Mr. Ashley Carter, A.M.I.Mech.E. The chair will be taken by the president, Mr. Charles Greenway.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, March 19, at 5 p.m., in the Rooms of the Geological Society, Burlington House, Piccadilly, W., when a lecture on "Atmospheric Conditions which affect Health" will be delivered by Mr. Leonard Hill, M.B., F.R.S., Director, Department of Applied Physiology, Medical Research Committee. The chair will be taken by Sir Napier Shaw, F.R.S., president.

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday, March 19, at 8 p.m., at the Royal Institution, Colquitt-street, when a paper will be read by Mr. John A. Davenport, M.Sc.(Vict.), B.Eng.(L'pool), Assoc.M.Inst.C.E., A.M.I.Mech.E., entitled "Welfare Work."

THE INSTITUTION OF MINING AND METALLURGY.—Thursday, March 20, at 5.30 p.m., at the Rooms of the Geological Society, Burlington House, Piccadilly, London, W. 1. The following papers will be submitted for discussion: "The Volatilisation of Gold," by Sir Thomas Kirke Rose, D.Sc., A.R.S.M. (Member); "Cobar Stope Measurement Methods," by Mr. W. S. Curteis (Associate).

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 20, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. Discussion on the recent lectures on "Dielectrics in Electric Fields," by Mr. G. L. Addenbrooke.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Friday, March 21, at 8 p.m., Joint Meeting and Discussion with the Royal Society of Medicine (Electrical Section), in the Barnes Hall of the Society, 1, Wimpole-street, Cavendish-square, W. 1. Papers by Mr. R. S. Whipple (Member) on "Some Notes on Electrical Methods of Measuring Body Temperatures," and "Some Notes on the Electro-Cardiograph."

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 21, at 6 p.m., at the Institution of Civil Engineers, Great George-Street, Westminster. General meeting. Paper: "Jigs, Tools and Special Machines with their Relation to the Production of Standardised Parts," by Mr. H. C. Armitage, of Birmingham, Associate Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, March 21, at 5.30 p.m, a discourse will be delivered by Professor W. W. Watts, LL.D., Sc.D., F.R.S. The subject will be "Fossil Landscapes." Afternoon Lectures at 3 p.m.:—Tuesday, March 18, Professor A. Keith, M.D., LL.D., F.R.S., F.R.C.S., M.R.I., Fullerian Professor of Physiology, Royal Institution, on "British Ethnology—The People of Scotland" (Lecture II); Thursday, March 20, Professor Charles H. Lees, D.Sc., F.R.S., on "Fire Cracks and the Forces Producing Them" (Lecture I); Saturday, March 22, Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., Pres.R.S., M.R.I., Professor of Natural Philosophy Royal Institution, on "Spectrum Analysis and its Application to Atomic Structure" (Lecture III).

THE METALLOGRAPHY OF ALUMINIUM.—A paper by Robert J. Anderson, of Cleveland, Ohio, in the January issue of the Journal of the Franklin Institute, is chiefly interesting for its many micrographs of the internal structure of aluminium, cast, cold-worked, hot-worked and annealed at different temperatures. There is also a good bibliography of 61 items, practically confined to the last decade and brought up to 1918. There are not many papers on the metallography of aluminium in this list; yet one should hardly think that information on the metallography of this metal is almost negligible as Anderson puts it. More information will probably become available with the restoration of normal conditions.

19,000-H.P. REVERSING ROLLING MILL MOTOR.

CONSTRUCTED BY MESSRS. SIEMENS BROTHERS DYNAMO WORKS, LIMITED, STAFFORD.

(*For Description, see Page* 342.)

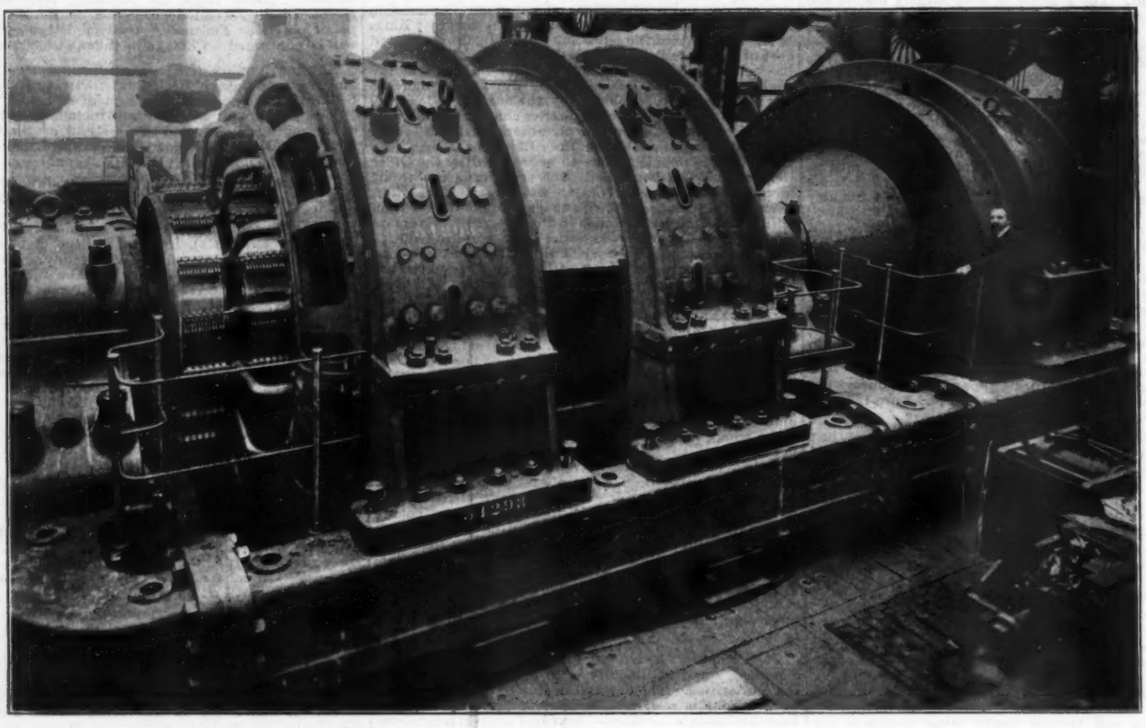


FIG. 1.

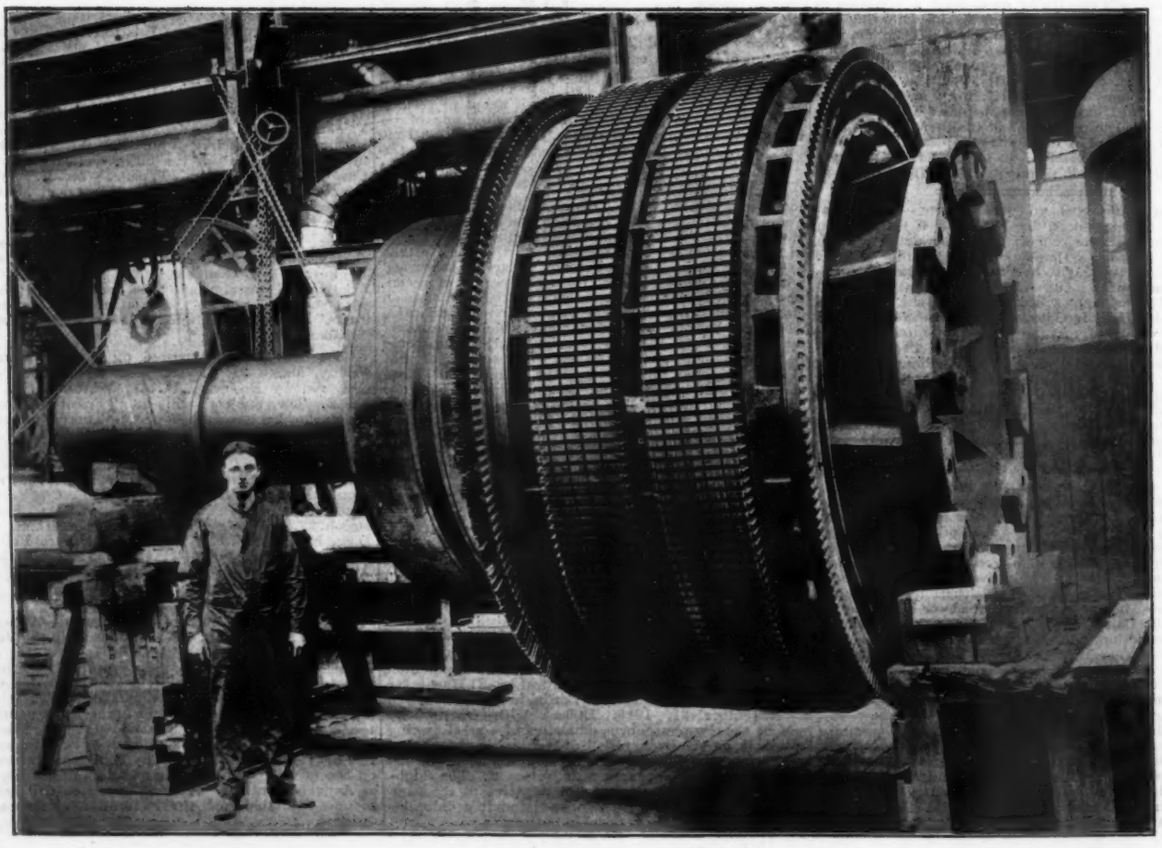


FIG. 2.

THE CONSTRUCTION OF A 400-TON REINFORCED CONCRETE BARGE AT BRENTFORD SHIPYARD.

MESSRS. J. AND W. STEWART AND MESSRS. STEWART AND PARTNERS, LIMITED.

(*For Description, see Page* 334.)

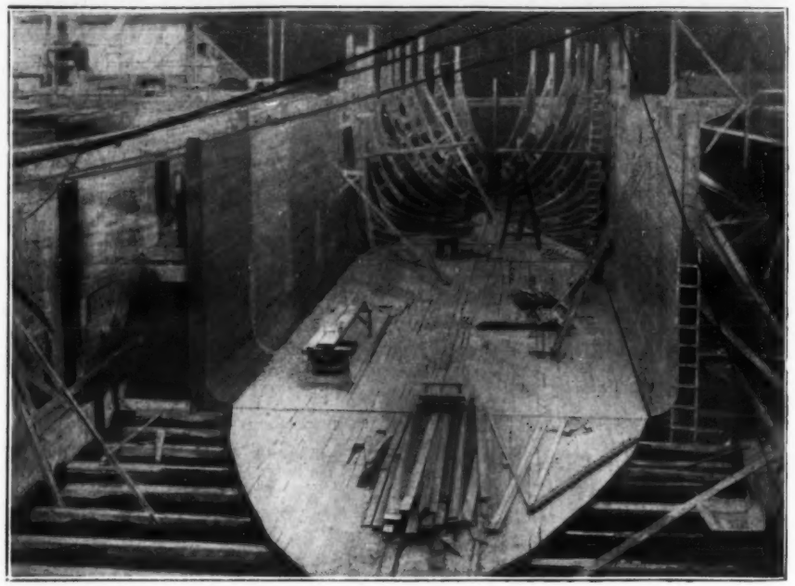
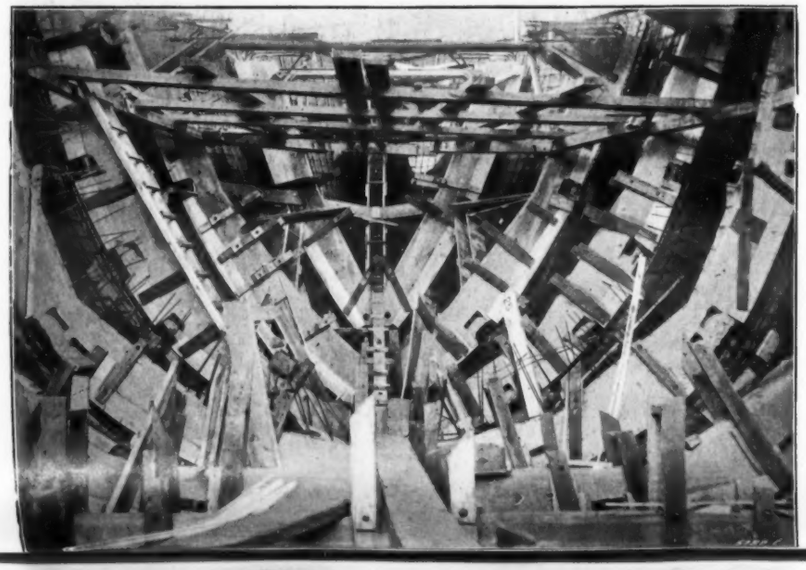
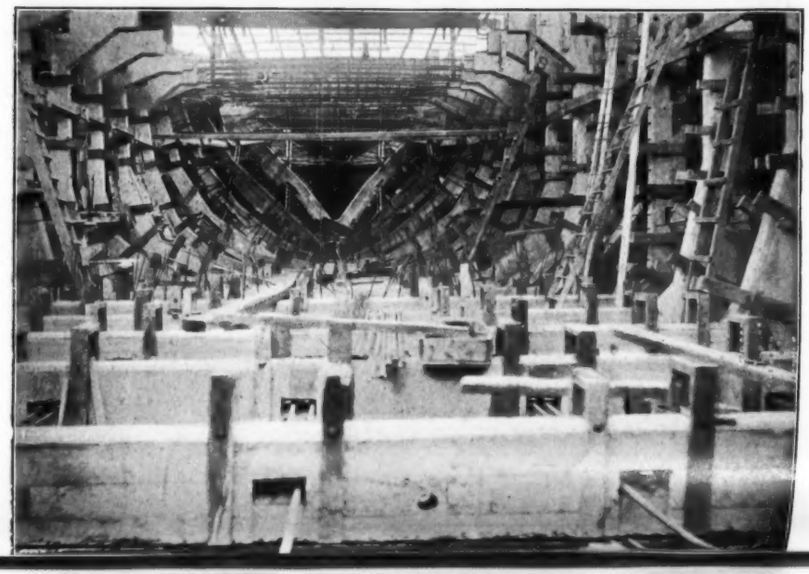


Fig. 2. Midship Shuttering and Wood Ribs for Shaping Bow.

Fig. 3. Wood Ribs for Shaping Stern.





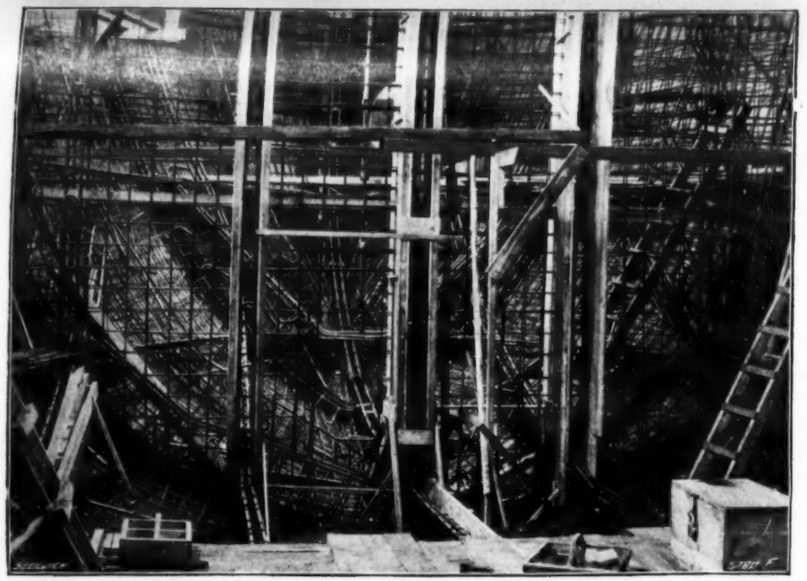


Fig. 6. Reinforcement for a Bulkhead near Bow.

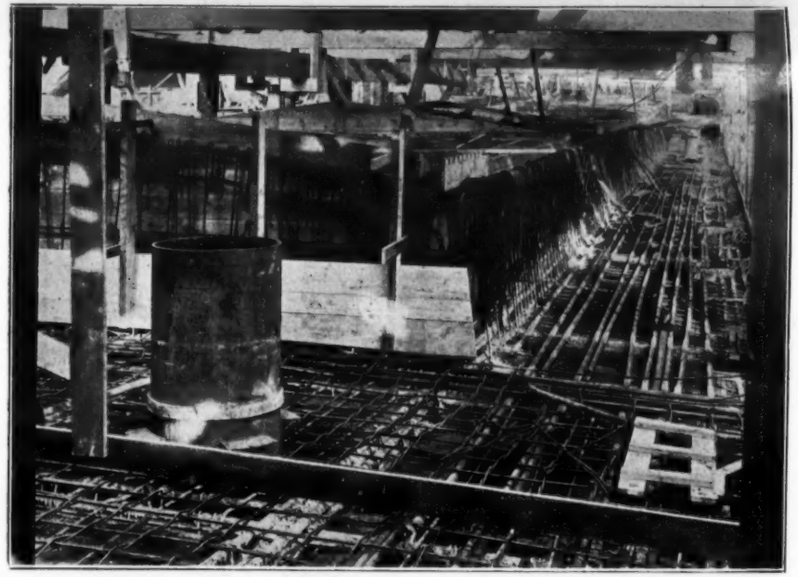


Fig. 7. Reinforcement for Deck and Hatchway Coamings.

Fig. 8. Exterior before Removal of Shuttering.

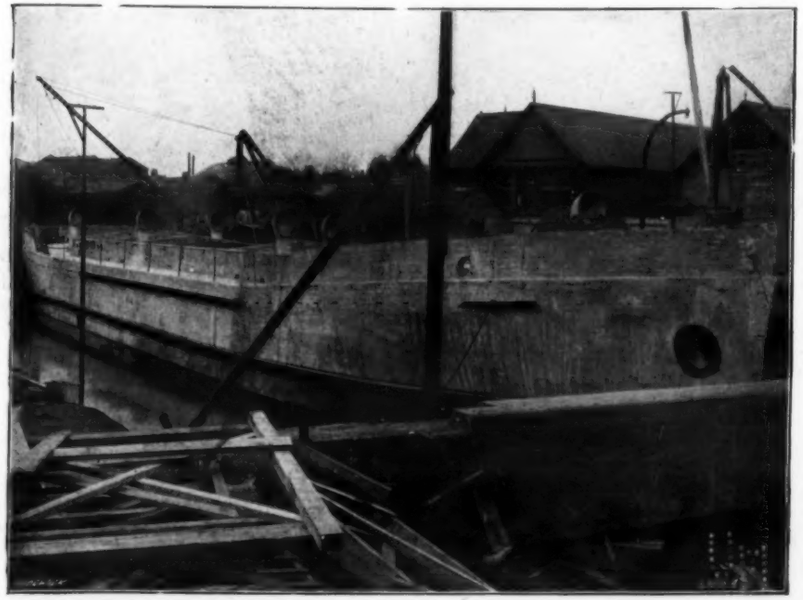


Fig. 9. Barge Afloat in Dry Dock.

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NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 343.

ENGINEERING.

FRIDAY, MARCH 14, 1919.

THE CULTIVATION OF TRADE RELATIONS WITHIN THE EMPIRE.

WE have kept our readers informed of the measures which have been developed during the war to assist in the cultivation of trade relations between this country and the various Dominions, Commonwealths and Unions of the Empire. On September 7, 1917, we explained that a new department was to be created, presided over by a newly appointed Parliamentary Secretary, which would have control of all work connected with commercial intelligence at the Board of Trade, and also at the Foreign Office, and that it would take over such of the staff and records of the War Trade Intelligence and Statistical Departments as were available and required. The official head of the department was to be appointed jointly by the President of the Board of Trade and the Secretary of State for Foreign Affairs, and would work under the new Parliamentary Secretary. The other appointments, notably those of the trade commissioners within the Empire, would, as before, be made by the Board of Trade, and those of the commercial attachés and consular services by the Foreign Office. On December 14, 1917, we announced that Sir Arthur Steel-Maitland, Bart., M.P., had been appointed Under-Secretary for Foreign Affairs and Parliamentary Secretary to the Board of Trade, thus forming the link between the two departments. We added that the new department had absorbed: (1) The Commercial Intelligence Branch of the Board of Trade, (2) the War Trading Branch of the Foreign Office, (3) the Foreign Trade Department of the Foreign Office, and (4) the consular services and whole Consular Department of the Foreign Office. The second and third of these are connected with the war, and will cease to exist in due course. An Advisory Council was to be formed, and it was hoped that our industries would be so organised as to provide means of communicating their desires to the Advisory Council, or to the department direct. In the recent rearrangement of the Government Sir Arthur Steel-Maitland retained his offices.

This question of overseas trade is one of immense importance, for our future depends on a great increase of export. On all sides we hear demands for better efficiency in our manufacturing methods, but that, unless accompanied with a widened demand for goods, involves great dangers. The feeling that lies at the back of the system of restricted production and of the movement for shorter hours is that there is not enough work to go round, and that increased output will produce glutted markets with a great increase of unemployment. It is easy to show that reduced prices must eventually stimulate demand, but that is little consolation to the man who finds himself out of a job while the demand is growing. The great and urgent need of the present day is to cultivate new markets and to expand the old ones, for on the attainment of this result lies the best remedy against the revolutionary doctrines now being preached to the working classes. Moderate prices at home, with good wages, and an active export trade to absorb all our output will not only bring prosperity, but will also foster content and peaceful co-operation among the working classes.

It is very much to be doubted whether our permanent officials are fitted by their training to undertake the extension of our overseas trade. They are excellent at compiling statistics and for noting the ebb and flow of demand, but their methods are too inelastic when new markets are to be sought and trade is to be tempted from an old channel into a new one. They are too apt to demand that definite results shall follow each action, and that a certain outlay shall be followed by an improvement in the statistics of imports and exports. They want faith and imagination, and have no knowledge of the patient and persevering efforts by which the great merchant firms have built up their businesses by sending travellers who for years have not paid their expenses, but who, all the time, have been making a connection which, once established, persists for years and ultimately amply repays the initial expense. The appointment of Trade Commissioners a few years ago furnishes an object-lesson. Four men, well qualified for such posts, were appointed, but they were not always sent to the countries for which they were best adapted by experience and linguistic ability. Nevertheless, they represented an excellent innovation on the former plans, and their numbers have since been raised to 16, and salaries have been increased up to a maximum of 1,200*l.* a year, with allowances extra. Every one must welcome this movement as being in the right direction, but its success will depend very largely on the spirit by which it is controlled, or, more properly, energised. Each of the gentlemen in question bears the title of "His Majesty's Trade Commissioner," and in India the holder of the commission has had his official status defined for ceremonial purposes as equal to that of a brigadier-general, and taking precedence of all consul-generals. This, of course, gives him an acknowledged position, which is an immense help to a newcomer desiring to get into touch with all kinds of existing organisations, and to foster the formation of new ones. But India is a unique country, and differs essentially from the Colonies and Dominions. In these official precedence is confined to the higher offices, and those in the lower ranks are left to make their individual marks as best they may. Further, the Home Government must not appear to dictate to the local authorities as to the position they shall accord to those who are sent over to seek new openings for trade, for the self-governing Colonies are naturally sensitive on such a score. It is laid down that the Commissioners cannot constitutionally represent the British Government. The only channel of communication is the Governor-General, and his position is akin to that of a constitutional sovereign who has no power of initiative, and who is in quite a different position from that of the Colonial High Commissioners, who can speak with authority and fully represent Colonial interests. Nevertheless, since the United States and other foreign countries can send specially accredited commercial representatives to the Colonies it ought to be quite possible for us to do the same without in any way offending local susceptibilities. It should not be difficult to make it clear that "H.M. Trade Commissioner" has the Government behind him.

The Trade Commissioners are in a delicate position in which they have to rely mainly on their personal qualities to obtain influence and to fulfil their functions. Failing official recognition, much could be done by the new department letting it be known that the Commissioners had their full confidence and that their representations would be adopted at home, without hypercritical scrutiny, as being the opinions of men on the spot who had studied the commercial conditions at first hand, and who could be trusted to recommend the right course. But to enable this condition to be realised it is clear that there must be great liberality in the matter of expenses and allowances. A Commissioner with an inadequate staff, so that he is burdened with routine work, is evidently at a great disadvantage, and is very liable to degenerate into a statistician. The first thing a newly-appointed man would naturally desire to do would be travel all over his appointed territory, and to address every Chamber of Commerce, every association of buyers and sellers, and every town council, explaining exactly what he represented and what he desired to do. He would follow this up by social intercourse with the leading men in each district, striving to learn in what respect our manufacturers had failed

to gain their confidence and satisfy their desires in the past, and in what respect they had come short of those of other nations. He would endeavour to foster trade organisations who could voice the requirements of their constituents, and at the same time to understand the colonial mind and to acquire its standpoint. His staff, meantime, would be employed in finding out quantitatively the needs of the colony in various classes of goods, and the purchasing power as measured by the available amount of raw material for export. When this was done, and it is no small task, the Commissioner would return home, and would proceed to reverse the process by explaining to our manufacturers what openings were available and how they could be filled. With such knowledge he could command large audiences in Sheffield, Bradford, Leeds, Manchester, Newcastle and Glasgow, and afterwards he would be welcome in many works and offices to elaborate the details of his address, and to guide the operation of the many federations and associations of manufacturers which have been formed since the war, and which are already making arrangements to send representatives to all the great markets of the world. A second visit to the colony would then gather up the ragged ends of co-operation and would consolidate schemes which had previously been tentative, due to the Commissioner not being fully informed on both sides of the question.

A programme of this kind cannot be successfully pursued unless the Commissioner feels fully assured of a very generous measure of support by the department. He must be certain that he has its full confidence not only in his honesty, but also in his discretion and in his initiative, and that his operations will not be followed in a carping or unduly critical spirit. His position should be analogous to that of a trusted partner in a firm, who journeys round the world to estimate the chances of trade and to open branches and connections. His expenses cannot be regulated by an official scale, or calculated by time or distance. If he can get one set of manufacturers to adapt their products to colonial ideas, so that they obtain full approbation, the result may be worth very many thousands a year to this country, in addition to the collateral advantage which will follow by more steady employment and industrial peace. Such a result would be cheap at a price which would be a severe shock to a Treasury official trained in the atmosphere of a pre-war age, and not awake to the new conditions which must be fully realised if we are to carry our burden of debt with a light step.

The appointment of Trade Commissioners is certainly a great advance upon the old commercial attachés, and cannot fail to have good results, though these may fall very short of what might be attained if all the possibilities of the system were realised. But the Commissioner is naturally not an expert in each trade; he must take a good deal on trust, and must rely on his general knowledge of business and of the world to prevent himself being led astray by the enthusiasm, or by the self-interest, of many whom he meets. His activities need to be supplemented by occasional visits from those whom the American Department of Commerce call "special agents." These represent a single trade, or group of trades, and are sent out to report on the prospects of a particular territory as a market for a certain class of goods. Agricultural machinery affords a case in point. The South American countries and our Colonies have received much attention from the point of view of their likelihood of being good buyers of American implements, either the standard machines, or modifications of them to suit local conditions. Clearly such a matter can only be dealt with by an expert. Even in our own small island we see different types of implements preferred in different districts, and manufacturers have learned by painful experience that they cannot safely force standard types on all markets. A Trade Commissioner is quite unable to deal with such a point, but it is one that should not be neglected in a great effort to extend our export trade, whether it be with our own oversea kinsmen, or with foreign nations. In smaller matters, not justifying the sending of a special agent, the Americans employ experts to frame carefully prepared "questionnaires," and these are sent out in the expectation that they will elicit valuable information. In the hands of a Trade Commissioner with a capable staff, such documents would go far to compensate for want of expert knowledge, for they would direct the lines on which inquiry should be made and afford clues which an intelligent man could pursue with advantage. There are already many federations and associations of manufacturers in this country who could give most valuable aid in drawing up such forms, and they would certainly do so if they had already made the acquaintance of the Commissioner, and had found that he was full of enthusiasm for his work and most anxious to receive their assistance.

The success of the new Department of Overseas Trade (Development and Intelligence) depends very largely by the spirit which animates it. If it is administered on the old Civil Service lines there is not much to be hoped from it. But we trust for better things. Already there are a number of new men in it, and out of returning military officers there ought to be many who have already had a thorough commercial training, but who, for some reason, find it difficult or undesirable to go back to the old groove and are on the look out for new opportunities, such as the department can afford. It is in the highest degree important that men of business experience should be selected, for it is only they who can understand the requirements of the time, and can adapt themselves to the rapid changes in methods which will be needed in the troublous days which lie ahead of us. Our Civil Service has qualities which have rendered it the envy of the world, but a knowledge of business forms no part of the preliminary training, and in later years the officials became steeped in methods which would prove disastrous to any commercial firm. With Sir Arthur Steel-Maitland as its head, the new department should cast off the traditions of the past, and pursue its career in a new spirit, seeking by every possible means, even if some of them appear revolutionary, to recommend our goods in all the markets of the world. Of the quality of these goods there is no doubt, and the price can be brought down if a large and steady demand can be created. The latter depends largely on a better understanding between buyer and seller, and this it is the business of the Trade Commissioners to create and foster.

THE RAILWAY SITUATION.

WHAT ultimately is to be the fate of our railways we would not like to attempt to say, but the talk of nationalisation and the present Government control have not yet touched the fact that the railways are still statutory companies, operating with private funds, and that in every fair sense of the word they are the property of their shareholders. In view of this one might have expected the various general meetings, which have been held during the past few weeks, to bring out some energetic protests against the cavalier treatment the companies have received. Actually, however, there was nothing beyond some few individual complaints, and the railway shareholder in general maintained his reputation as a patient animal.

Of the general situation there was nothing to be learned from these meetings. The directors could only tell their audiences that after Mr. Churchill's statement about nationalisation, a deputation of railway chairmen waited on Mr. Bonar Law and Sir Albert Stanley and were informed that the whole question was under consideration, but that in any case the present control with the guarantee of the net receipts for 1913 would be continued for two years after the formal signing of peace. This was merely a reaffirmation of an assurance which had been made by Mr. Runciman, then President of the Board of Trade, in September, 1916. For the moment, then, the shareholder has something over two years during which he is reasonably sure of his pre-war dividend and as determining the period after that, there is yet time for many things to happen.

We think it improbable that the railways will ever revert to the state of comparative freedom they enjoyed in 1913. Nationalisation out-and-out and various forms of control will be discussed in the next two years and will have to be examined properly, and it is to be hoped that the best decision from all points of view will be assisted by the publication of adequate financial data. For the moment, the wages increases, imposed from outside, coupled with the rises in the costs of materials, have apparently led to an unsound financial position. The available information is, however, very incomplete. The returns made by the companies show the cost of the enormous Government traffic which has been dealt with, but show no receipts from this traffic. There is thus no proper relation between receipts and expenditure given. Another factor which must be borne in mind in a consideration of the present financial position of the railways is that they have dealt with much greater traffics than ever before with a much smaller *personnel* than in 1913. Certainly the facilities in some directions have not met all requirements, but none the less, the fact cannot do other than suggest possibilities of future economies.

The records of the railways from a technical point of view, which the chairmen presented at the various meetings, were at once stories of very great things and very small things. The war work accomplished has been very great. The developments towards a normal peace traffic have so far been very small. A complete record of war achievements would involve a list of figures which we have not space for, but some indication of what was done should be of interest. We will confine ourselves in the main to the work on the Great Western Railway as a fair example of what was achieved throughout. On this system the train mileage increased 12 per cent., as compared with the decade prior to the year of the outbreak of war, the number of passengers increased 30 per cent., the number of season-ticket holders 236 per cent., and the tonnage of freight 41 per cent. These figures were, of course, obtained with a depleted stock and a depleted staff. Some idea of what the depletion of the stock meant is given by the facts that up to the end of December of last year the company had provided 216,350 wagons exclusively for naval and military movements, had set aside 638 passenger coaches for new services run in connection with munition works and 46 for ambulance trains in this country. In addition, 95 locomotives and 6,567 wagons were supplied for use overseas, while 238 coaching vehicles were converted for ambulance train work and other purposes abroad. Of the staff, 25,479, or over 32 per cent., were enlisted in the Army, Navy, and Air Forces. It was under these conditions that in eight or nine months last year 1,139 special trains conveying American troops, mainly from Liverpool and Glasgow, were run over the Great Western line. Approximately an equal number of empty trains had to be returned to the landing ports. In one day 28 of the trains passed over the system, of which 21 halted at Snow Hill Station, Birmingham, where the troops numbering over 10,000 were served with refreshments.

Parallel figures to the above could be quoted for any of the railways. For instance, the South-Western ran 58,000 special trains for the War Office and Army Commands. In these were conveyed 20,000,000 officers and men, 1,500,000 horses, 11,000 guns, 475,000 vehicles with baggage and stores, and over 2,000 tanks. The Great Eastern have run 12,000 special trains, carrying 5,935,365 men, 232,370 horses, 38,689 vehicles, 42,395 cycles, and 40,000 tons of baggage. They have worked 1,140 ambulance trains, and lost 30 per cent. of their original skilled staff owing to enlistment. The Midland Railway Company ran 18,000 special trains, conveying 2,400,000 officers and men, 175,000 horses, 25,000 tons of baggage, &c. At the meeting of this company, the chairman referred to the "extraordinary punctuality" which had been achieved in spite of the reduced and diluted staff. In 1918, there were 24,164 express trains, and of these, 87 per cent. were either punctual or not more than five minutes late, while of the total of 388,617 local trains, 92 per cent. were either punctual or not more than five minutes late. Referring to mineral trains passing Melton, a point where trains from eleven different coal centres converge, out of 22,488 mineral trains, 73 per cent. were either to

right time or not more than ten minutes late. In addition to the extra genuine railway work which was thrown on the companies, almost all of them undertook war manufacture of some kind in their shops. The list, which we need not give, covers not only railway material, such as ambulance trains and signal boxes, but shells, fuses, bombs, gun parts, cartridge cases, &c.

Turning now to what has been done towards a return to peace conditions, the most important present considerations are the shortages of coal, stock and skilled staff. We gather from remarks of various of the chairmen that shortage of stock and particularly of locomotives, is the greatest difficulty at the moment. The Right Hon. Lord Claud Hamilton, at the meeting of the Great Eastern Railway dealt with this matter in rather greater detail than some of the other chairmen. He stated that it had been the intention in November last to expedite repairs and renewals of engine stock in order to have been in a position to resume pre-war normal services next Easter. This programme was, however, completely upset by the introduction of the 47-hour week. On November 1st last the company had 893 locomotives in road-worthy condition, and by the end of December the number had risen to 971, which appeared to promise well for the future. The 47-hour week was then introduced, with the result that by the end of January the figure had fallen to 883. Figures of this kind clearly indicate that the sudden introduction of the 47-hour week at a critical stage, has further increased the difficulty of getting back to something like a normal service, and that the public and the business community will be hampered in their movements longer than was necessary.

Positive advances so far made consist mainly in the speeding-up of some main line trains and the restoration of a proportion of the luncheon and dining car services. On this latter point, the chairman of the London & North-Western stated that tea cars have already been added to certain trains, and it was hoped to restart the dining cars on some of the Scotch trains this month. The North-Eastern hopes to do the same and has already put restaurant cars on four trains between London and Newcastle. The Brighton line is hoping to start the "Southern Belle," and some of the first and third-class Pullman trains in May. The South-Western reports the final abolition of the second-class carriage during last year, owing, mainly, to the increased extent of the electrical service which has only two classes. In connection with electrified services, the chairman of the North-Western Railway announced that the restriction placed by the Government on the completion of the last section of the new Watford line—that between Chalk Farm and Queen's Park—had now been withdrawn, and that arrangements were in hand for completing the works. It was, however, impossible to fix a date for the delivery of the new rolling stock necessary for the Watford line. The chairman of the North London Railway, referring to the same matter, stated that in spite of the restricted service, electrification seemed to have checked the fall in passenger traffic which had had to be reported for some years past. At the City & South London meeting, it was stated that the first preparations were in hand towards the modernisation of the line. The cost was expected to be 70 per cent. above the original estimates. This is probably much the most expensive railway scheme now in hand in the country. There are, indeed, naturally very few new schemes of any sort, costly or otherwise, but it may be mentioned that the North-Western and Lancashire & Yorkshire Companies are to promote a Bill for the construction of a short branch to Cleveleys from Thornton on the existing joint line. This is to facilitate the Blackpool and Fleetwood traffic.

THE DYNAMICS OF FLYING.

On Monday afternoon last, Capt. G. P. Thomson delivered, at the Royal Institution, his second aeronautical lecture,* which was entitled "The Dynamics of Flying." This lecture was to have been delivered on the 25th ultimo, but had to be postponed owing to the lecturer's illness.

* For report of first lecture see page 246 ante.

In opening his remarks, Capt. Thomson said that in his previous lecture he had dealt with the subject of longitudinal stability, and had considered pitching and vertical motion in the plane of symmetry of the aeroplane. He proposed, in the present lecture, to deal with the more complicated subject of lateral stability. The subject, he said, was more complicated because of the three-dimensional character of the motion, it being difficult to form a mental picture of the combined motions of yawing and rolling.

The two features most affecting the lateral stability of an aeroplane were the fin area and the dihedral angle of the wings. The effect of the fin on lateral stability was analogous, the lecturer said, to that of the tail in longitudinal stability. If the fin were too small, the machine would lack directional, or weathercock, stability, and would tend to turn so that its tail was in front. It was, however, possible to have a machine slightly unstable statically in this respect, but just stable dynamically, owing to the interaction of the various kinds of motion which tended to improve stability. If, however, the area of the fin were reduced much below that required for weathercock stability the machine became unstable, and the oscillations set up would increase in amplitude until eventually it would turn over. A still further reduction of fin area, or what amounted to the same thing, the addition of fin area in front of the centre of gravity, would have the effect of changing the unstable oscillations into a spin. These effects were demonstrated by means of model gliders launched from the gallery. The first of these had just insufficient fin area, but showed itself to be on the verge of stability by first, apparently, rolling about its longitudinal axis, and finally falling. In a second model, which had a fin in front, the instability was much more marked, this being indicated by the fact that the model practically refused to fly at all.

Continuing his remarks, the lecturer explained that, while at the present time no designer deliberately placed fins forward of the centre of gravity, the air screw of a tractor machine nevertheless acted as a fin, and had an important effect. Another feature which affected this matter was the fuselage. If a stream line body of circular section were placed in a current of air and attached by a short string from its nose to some fixed point, it would not, as might be supposed, set itself in line with the wind, but would veer round to some comparatively large angle with the current. This fact was accounted for by the situation of the centre of pressure, which was actually in front of the nose when the air current was either parallel to, or made a small angle with the axis of the body. As the fuselage of an aeroplane was of more or less streamline form it followed that a similar effect was experienced, and this, as well as the effect of the air-screw, had to be balanced by the tail fin. This, the lecturer demonstrated very effectively by means of model gliders. A model, having a somewhat larger fin than that first mentioned above, flew quite stably, but oscillated considerably, while in another model, with a still larger fin, the oscillations were rapidly damped out, so that its flight was quite steady.

The fin area, however, could not be increased indefinitely, as the effect of a very large fin was to introduce instability of another kind. A model with what would be regarded in practice as a ridiculously large fin, was then launched, and this, after a very short flight, came spinning to the ground. The lecturer explained this by pointing out that if the aeroplane tilted to one side it would commence to side slip, and the high resistance of the unduly large fin to lateral motion would, at the same time, cause the machine to turn. The outer wing would then be moving faster than the inner wing, and the increased lift on the outer wing would cause the machine to bank. This still further increases the rate of turn until the nose points vertically downwards. The effect could, however, be counteracted in two ways. The most obvious, but at the same time the least effective, method was to use a fin at some distance vertically above the centre of gravity of the machine. The effect of this fin, when a side slip commenced, would be to roll the machine in a direction which would decrease the bank, and so bring it back to a level keel. A much more effective method, however, was that usually adopted, viz., to set the wings at a dihedral angle. The result of this arrangement was that, in the event of a side slip, the effective angle of incidence of the wing on the inner side of the turn was increased, and that of the outer wing diminished. The inner wing thus gave greater lift, and the outer wing less lift, and in this way, the equilibrium was restored. The dihedral, in fact, acted as a very powerful fin situated above the centre of gravity. It was, the lecturer continued, quite possible to fly a machine without dihedral, even with a large fin area, as the type of instability resulting was not very violent and could be controlled by the pilot. At the same time, most modern British machines had the wings set at a dihedral angle, owing to the increased comfort which resulted from this arrangement.

With regard to the value of stability in aeroplanes, there was some difference of opinion among pilots. Some pilots preferred a somewhat unstable machine, especially for fighting, for the reason that such machines were thought to be more quickly manœuvred. Much depended, the lecturer thought, on the pilot's previous experience. A stable machine certainly might require more effort to cause it to execute the complicated evolutions used in aerial combats than an unstable machine, but, otherwise, the lecturer doubted whether instability was any advantage, even for fighting. One of our most successful fighting scout machines, the S.E.5, he said, was quite stable, and he had heard no complaints as to its controllability. An unstable machine was tiring to fly, as the pilot had always to be adjusting the controls, whereas on a stable machine the controls needed practically no attention in ordinary flight. Moreover, some machines, which were longitudinally unstable in normal flight, proved to be very stable when flying upside down, and some fatal accidents had occurred owing to the inability of the pilot to right the machine from an inverted position which it had taken up as a result of a loop, or some other manœuvre. Another objection, which applied more especially to large machines, was that when diving steeply, the effort required to restore the machine to a horizontal flight path might, in an unstable machine, easily exceed the strength of the pilot. The present position, the lecturer said, was that all service machines were required to be stable, except single seaters, and a good many of the latter type were also stable. Bombing machines, especially, should be quite stable, to enable the bomber to take accurate aim. It was found that in moderately calm air a stable machine, if left to itself, would keep much more nearly level than when controlled by the pilot.

The first really stable machine to be used in actual warfare was the B.E.2c, which was introduced towards the end of 1914. This was a two-seater tractor, intended for general reconnaissance work, and it was a great improvement on previous designs. At that time aerial fighting had hardly begun, and even photography and co-operation work with artillery, were in their infancy. Except for a few machines like the Vickers, reconnaissance was regarded as the chief work of aeroplanes, and consequently the B.E.2c was designed with the observer in front and the pilot behind. This afforded the observer a good view in most directions, and also had the advantage that, as he sat practically at the centre of gravity, the machine could be flown with or without a passenger without altering its trim. For fighting, however, the design was obviously bad, as the field of fire was obstructed in front by the air-screw and at the back by the pilot's head. The type, therefore, was subjected to much criticism at a later date, owing to the action of the authorities in persisting with this design at a time when fighting had become a matter of primary importance. The performance of the machine was, however, gradually improved by a number of small modifications, until, in its final form, its speed near the ground was about 90 m.p.h., and the climb was 6,000 ft. in about 20 minutes. It is interesting to note that the speed was increased by 5 m.p.h. by substituting bracing wires of lenticular section for the round cable used in the original design.

The F.E.2b, the lecturer continued, represented a second type of stable machine. This machine was

specially designed for fighting, and, being of the "pusher" type, it gave an excellent field of fire forward. Its performance, however, was not good, the speed, with a 120-h.p. Beardmore engine, being about 80 m.p.h. Generally speaking, pusher machines were heavier, and had a higher resistance than those of the tractor type. The F.E.2B was introduced early in 1915, and, as it was still in use at the termination of hostilities, the life of this type was probably longer than that of any other used in the war. The engine power was increased from 120 h.p. to 160 h.p., and for the last two years of the war the machine was used almost exclusively for night bombing, for which work it was well suited, owing to the excellent view afforded. Its slow speed was not very detrimental in night flying, as the possibilities of encounters with fast scouts were remote.

In the course of 1915, the lecturer said, fighting in the air became of greatly increased importance. On our side, fast single-seater scouts, such as the Bristol and Martinsyde, appeared, and the enemy produced the Fokker monoplane, which was a copy of the French Morane. The practice of using a fixed gun firing through the propeller now became common, and this removed one of the previous drawbacks of the tractor type of machine. The device originally used for this purpose was a mechanical interrupter gear, which, the lecturer thought, was introduced by the French, though it was first used on a large scale by the Germans. Later, the mechanical device was replaced by an hydraulic wave system of transmission, invented by a Roumanian, M. Constantinescu, and this system had been in use on British aeroplanes for the last two years.

With the development of aerial fighting, the importance of manœuvring, or what is popularly known as "stunt" flying, became more and more marked, and one of the most interesting features of the war, from an aeronautical point of view, was the advance made in this branch of flying. To-day pilots of a few months' standing could perform manœuvres which, even a year or two ago, were almost unknown. These manœuvres, although sometimes regarded as the least useful part of flying, were often of great assistance to the fighting pilot, though, at the same time, it could not be denied that the most successful fighters were not always the best pilots. One of the commonest and simplest evolutions that came within this category was the ordinary loop. To perform this manœuvre it was usually necessary first to increase the speed by putting the nose of the machine down. If then the control lever is pulled right back, the machine will loop. The effect of pulling back the control lever is to raise the elevators, and this causes a downward force on the tail which tilts up the nose. The increased angle of incidence of the wings produces an increase in lift which forces the machine bodily upwards. During this movement, the nose turns up more and more, and, as the force on the wings acts always more or less normally to the flight path, the machine continues to fly along a curved path in a vertical plane until it eventually regains its normal position. The path followed by an aeroplane in a good loop is, however, by no means circular, the radius of curvature being made much less at the top of the curve than at the bottom. The object of this is to reduce the stresses on the wings. Centrifugal force, of course, acts always radially outward from the centre of curvature, so that, at the bottom of the loop the wings have to support this force in addition to the weight of the machine, while at the top of the loop the centrifugal force is subtracted from the weight. Thus, if the curvature of the path at the bottom of the loop, where the speed is high, is too great, the wings may be torn off, while at the top of the loop the centrifugal force should be made large by increasing the speed and the curvature of the path as much as possible, as, unless the centrifugal force is here greater than the attraction of gravity, any loose objects in the aeroplane will fall out. The manœuvre known as the "Immelman turn," may be regarded as a variant of the ordinary loop, from which it differs in that the motion is not confined to one plane. This manœuvre gives a rapid turn without inducing excessive stresses.

Another very characteristic type of motion is known as a "spin," but this manœuvre must not be confused with the spinning instability above referred to. This evolution can be performed on a perfectly stable aeroplane by suitably setting the controls. An aeroplane may be made to spin by first stalling it gently, and then quickly putting the rudder right over. This causes the machine to swing violently, turn its nose downwards, and commence to spin. The spin can then be made more rapid by holding the control lever over to one side so that the ailerons act in the opposite sense to the rudder. This and the two previously mentioned manœuvres, were most strikingly demonstrated by the lecturer using glider models similar to those previously used in the experiments on stability. Spinning, the lecturer continued, presented some interesting features, and this type of motion had been very fully investigated at the Royal Aircraft Factory, Farnborough. At first, it had been difficult to find a reason for the comparatively slow downward speed of an aeroplane while spinning. The speed did not usually exceed about 50 or 60 m.p.h., whereas, if diving without spinning, the speed might rise to something like 200 m.p.h. This was eventually accounted for by the resistance of the wings, which is very high during a spin, even though the speed is low, owing to the large angle of incidence. During a spin, the incidence of the wings may vary from about 15 deg. at the outer wing tip to about 40 deg. at the inner tip, and wing resistance was known to increase very rapidly at angles of incidence greater than the stalling angle of about 16 deg. Other features, which could also be explained by the fact that the wings were stalled in a spin, were the extreme rapidity of the turns, and the unexpected action of the ailerons. In normal flight, the effect of the ailerons is to tilt the machine upwards on the side of the aileron that is down, but in a spin the reverse action takes place. This can be readily understood if it be remembered that at ordinary flying angles the lift increases with the angle of incidence, but beyond the stalling point an increase in the angle of incidence diminishes the lift. These effects, as can easily be imagined, accounted for numerous fatal accidents before they were properly understood, the natural tendency being for the pilot to move the control lever in the opposite direction to that actually required to recover from a spin.

In concluding his very interesting lecture, Capt. Thomson expressed the opinion that, in the immediate future, progress was to be looked for rather in the direction of improvements in engines than in any very remarkable modifications in the design of aeroplanes themselves. Great progress had, undoubtedly been made in engine design during the course of the war, but a perfectly reliable engine was still the most important desideratum for progress in aviation.

INSTITUTION OF NAVAL ARCHITECTS.

THE Council and the Secretary, Mr. R. W. Dana, are to be congratulated on the complete programme and the diversity of subjects arranged for the spring meeting of this Institution, which opens on April 9. These meetings have been held annually throughout the period of the war, notwithstanding the fact that the members were so engrossed in the production of vessels for the Navy, and that it was not possible to deal with the work being carried on. It is, therefore, gratifying to find that the work done is to be dealt with in a comprehensive way, first by a paper by Sir Philip Watts, K.C.B., formerly Director of Naval Construction, who will deal with the vessels built or in progress at the outbreak of the war, while the supplementary title "Some Matters of Interest in Connection with Their Production," is sufficiently comprehensive to open up a very wide field. There can be no doubt, however, that a still more important paper is that promised by the present Director of Naval Construction, Sir Eustace T. d'Eyncourt, K.C.B., as it will deal with naval construction during the war, and thus we shall have disclosed for the first time, the enormous development that has taken place, notably, in light cruisers, torpedo-boat destroyers and many auxiliary ships of the Navy. It is a subject for regret that there is not a corresponding paper dealing with the engineering side of warship construction and design. The third paper to be read at the meeting on Wednesday is of a kindred subject to warship construction, having reference to the Naval Construction Corps of the United States Navy, the author being Mr. S. V. Goodall, a member of our own Royal Corps of Naval Constructors.

At the morning meeting on April 10, the first item of business has reference to the proposed alteration of the bye-laws, in order to admit women to all grades of membership on the same qualifications as men. Following this, Mr. A. E. Seaton will read a paper on "The Work of the British Marine Engineering Design and Construction Committee," which, it will be remembered, was set up to ensure some uniformity in the regulations of the government departments and registration societies. The next paper is by Mr. S. Orlando, and is on the "Italian Two-Floodable Compartment Cargo Steamers Built During the War," while a paper on a kindred subject, "Some Recent Developments Towards a Simplification of Merchant Ship Construction," is to be contributed by Sir Eustace Tennyson d'Eyncourt, K.C.B., and Mr. T. Graham, both of whom were responsible for the design of the "fabricated" ship. The first paper at the afternoon meeting, on April 10, is on the "Development of Airship Construction," and is by Mr. C. I. R. Campbell, R.C.N.C. It is gratifying to see that the Institution of Naval Architects are taking interest in the design of naval airships, as the problems are analogous to those of floating bodies. "Concrete Shipbuilding in the United States of America," will be dealt with by Mr. W. L. Scott, of Lloyd's Register, at the same meeting. The Thursday evening meeting is usually concerned with engineering problems, and this year there is to be no exception to the rule. A paper on an "Investigation Into the Case of Corrosion and Erosion of Propellers" is bound to give rise to very considerable discussion, particularly as the subject is to be introduced by Sir Charles A. Parsons, K.C.B., and Mr. Stanley S. Cook. Following this, at the evening meeting, will be a paper by Mr. J. Hamilton Gibson, on "The Michell Thrust Block."

Meetings will be held in the forenoon and afternoon, on the Friday. At the former, three papers will be read, one by Mr. W. H. Gard, on "Some Experiences with Electric Welding in Warships." The second paper is on "Further Experiments on the Stress Determination in Flat Steel Plates," by Dr. J. Montgomerie, and the third on "The Tonnage of Modern Steamships," is by Mr. A. T. Wall. At the afternoon meeting, Mr. J. L. Kent will read a paper on "Model Experiments on the Effect of Beam on the Resistance of Mercantile Ship Forms," and Mr. J. Semple will contribute a paper on "Some Experiments on Full Cargo Ship Models."

INSECT PROBLEMS.

A SLIGHT rearrangement of the Royal Institution lecture programme having become necessary Professor H. Maxwell Lefroy added three lectures to his instructive discourse on "Insect Pests" which we noticed on page 298 of our last issue. Two of these lectures dealt with the Silk Industry in British India, the last with further Insect Problems. The subject deserves serious general attention. Whilst France, having a silk industry of her own, encouraged silkworm breeding and silk spinning in her colonies, Professor Lefroy pointed out, the British Government, having no silk industry except in India, did little to assist the million people occupied in this languishing home industry in the Indian Empire (including Kashmir, Assam and Burmah), or to prevent the decay which threatens it. This would be a great pity, we agree with Professor Lefroy, who warmly feels for the native workers. For apart from certain abuses, which earnest endeavours could stop, silkworm raising, cocoon reeling and spinning and silk weaving, suitably employed and sustained many men, women and children who had no other resources and who, owing to the peculiar religions and social conditions of India, could hardly take up other professions. India, moreover, did not by any means supply even her own wants of silk. Much silk was imported from China and Japan, especially the "tasar" or

"tussore" silk. Like the "muga" silk (from Assam) and the "eri" silk (from Orissa), this silk was produced by wild caterpillars, which were largely domesticated, however, whilst the ordinary mulberry silkworm was entirely domesticated. The "eri" silk was the only one the moth of which was allowed to escape from the cocoon, and was for this reason alone worn by strict Hindoos; in the other cocoons the chrysalis or moth was killed. The killing was done by the heat of the sun or in furnace houses. This latter work was exceedingly unhealthy, and the sweating among the most accomplished weavers in Madras (earning 2*d.* a day) disgraceful; otherwise the industry was not unwholesome, however. Professor Lefroy and his fellow members of the Royal Commission had tried to help the workers in their fight against natural enemies and to improve the primitive devices in use; on returning to England, however, they had found that their "inventions" had long been known in Lancashire, and their report of 1916 had had the usual fate of being shelved.

In his last lecture, Professor Lefroy reviewed various solved and unsolved insect problems. Entomologists had been able to stop the destructive work of the sugar-cane moth and caterpillar in West India by studying the habits of the insects and of their parasites. In the case of the potato moth—not the Colorado beetle of former decades—which laid its eggs into the tubers and which had spread from Central America, the home of the potato, they had in India discovered that burying the seed potatoes in dry sand afforded a protection against that pest; but the moth had recently been observed in Paris, and it might come to England. The ordinary American bollworm, which destroyed the buds and the capsules of the cotton plants to get at the seeds had done very serious damage in India in 1905 after a severe winter; after their fight against it had been almost a gamble, but they had discovered a remedy by introducing a parasite (a kind of fly laying its eggs into the worm) from unaffected districts into districts which the cold had visited; the cold had killed the parasite, but not the bollworm. The pink bollworm, however, the caterpillar of which wintered in the seed, had found its way into the cotton fields of the Southern United States in spite of the careful watch which the United States kept on all imported produce, and when Professor Lefroy was over there in 1917, the situation had been considered decidedly serious.

The next case upon which Professor Lefroy dwelt was again more satisfactory. It concerned the decay of the magnificent timber roof of Westminster Hall, an arched structure 69 ft. wide, 90 ft. high, originally designed as stone architecture evidently, but carried out in English oak. We dealt with the report by Mr. F. Barnes on this much-discussed problem in our issue of June 26, 1914; the work of restoration is still proceeding. Though Professor Lefroy spoke mainly as an entomologist, his remarks have interest for the engineer as well, and the chemicals now used are not those mentioned in the report. The decay is largely the work of the larva of a beetle, about ¼ in. long only, which, living on willows and oaks is harmless. But it lays its eggs in cracks and fissures of the wood, and the larva eats its way into the wood and bores long passages, turning into a chrysalis at a spot from which the beetle can afterwards escape; for the beetle could not work its way through the wood. The task was thus to poison the larvæ, to preserve the wood and to prevent the beetles from finding cracks for their eggs. As the beautiful brown colour of the timber was to be preserved, corrosive chemicals were out of the question; creosote turned this oak red in streaks; poisons like arsenic were ruled out because they would poison the atmosphere of the Hall, and water could not be used as solvent for any chemicals because it would favour cracking of the wood. Thus tetrachlorethane was adopted as solvent and later replaced by ortho and para-dichlor benzene, which can be used without forcing the men to put on masks during the spraying process. The chemicals dissolved in the liquid are 2 per cent. each of soap, of cedar wood oil, which seems to be distasteful to the beetles, and of paraffin wax; the liquid penetrates into the wood and does not evaporate, and the wax forms a solid surface coating stopping the cracks. The beams of the timber have to be taken out and treated singly, for this spraying process; how the structure is otherwise reinforced with steel, was explained in our previous article. Professor Lefroy mentioned that St. Paul's Cathedral had a similar though less serious problem to face; but there was no question in that instance of preserving the colour of the timber.

Professor Lefroy finally referred to some other unsolved problems, some very real to us already, but little heeded. The sleeping sickness is spreading in and from Africa, in spite of all efforts to stop it; malaria has its recognised breeding-places in several districts of England; the sheep-maggot kills many sheep in this country; what the rat, the louse, and the flea can do as carriers of disease the war has taught us; and the common house fly is a terrible enemy to infants in particular. The damage done to our orchards, especially to apple, pear and cherry trees, by the codlin moth, the woolly aphis and other insects, was generally underrated. Some of those insects did not only ruin individual apples, &c., however, but weakened the trees so that they did not bear any healthy preservable fruit. Thus we became more and more dependent upon imported fruit. Entomologists were not as a rule considered to be desirable members of Government Commissions of Inquiry, however, and their services were hardly wanted in this country, though better appreciated in the Dominions.

INDUSTRIAL NOTES.

THE sittings of the Coal Mines Commission commenced on Tuesday, the 4th inst. The first witness heard was Mr. A. L. Dickinson, adviser to the Coal Control Board, who gave figures for output per person over various periods, which we recorded on page 317 *ante*. In the course of his statements, Mr. Dickinson said there were in the United Kingdom about 1,452 coal owners, of whom 434 were small owners having an output of about 2,000 tons per year. The number of mines or pits in the United Kingdom was about 3,300. Of the excess profit tax, 15 per cent. went to the Coal Controller, 5 per cent. to the owners and 80 per cent. to the revenue. The average output of the five years ended 1913 was 270,000,000 tons per annum. The average value at the pit head was 8*s.* 9*d.* per ton. The profit before charging royalties and interest was 19,000,000*l.* After deducting the royalties, which amounted, and still amount to 6,000,000*l.* per year, the profits to the mine owners on share and loan capital were 13,000,000*l.*, or just under 1*s.* per ton on the 270,000,000 tons raised. We give below the figures for the five years average to 1913 and for the following periods, taken from Mr. Dickinson's statements:—

Period.	Output in Tons.	Value at Pithead.	Profit, less Royalties.	Profit per Ton.
		s. d.	£	*s. d.*
Average for five years to 1913 ..	270,000,000	8 9	13,000,000	1 0
1914.. ..	266,000,000	9 11½	15,500,000	1 1½
1915.. ..	253,000,000	12 5½	21,500,000	1 8
1916.. ..	256,500,000	15 7½	38,800,000	2 11
1917.. ..	248,500,000	16 8½	27,750,000	2 2½
1918 to Sept., annual basis	218,000,000	24 10	30,000,000	3 6½

Mr. Dickinson further said that the reduction in hours would mean an increase in the cost of coal on the September, 1918, figures of 2*s.* 7*d.* per ton; the increase in wages would mean a further increased cost of 4*s.* per ton, making a total of 6*s.* 7*d.* per ton. Basing an estimate on figures supplied by experts, he found that the reduction of hours from eight to six would mean a 20 per cent. reduction in output. In reply to a question, Mr. Dickinson also stated that the total cost of coal, provided the hours were reduced and the wages increased 30 per cent., would be 27*s.* 10*d.* per ton; he added that if the hours were reduced, the workers who were paid piece rates would not earn so much, and he had made allowance for that.

At the sittings of Wednesday and Thursday, the 5th and 6th inst., the Commission dealt with output and cost, margins of profit, the American competition, the position of small traders and the Admiralty contracts.

At those of Friday and Saturday, the 7th and 8th inst., Mr. Benjamin Talbot gave evidence on behalf of the National Federation of Iron and Steel Manufacturers. He stated that the iron and steel industry consumed at least one-seventh of the total amount of coal in the country; the consumption was about 4 tons of coal per ton of finished steel. The pre-war production of steel in the United Kingdom was about 7,000,000 tons, and when the extensions at present in progress were completed, the capacity for production would be about 12,000,000 tons of ingots per annum. America's pre-war production was about 31,000,000 tons and the probable present capacity about 43,000,000 tons. Before the war, we exported 5,000,000 tons and America 2,700,000 tons. When the Government subsidy was removed next month, we should be paying for blast-furnace coke 39*s.* per ton, at the ovens, as against the United States price of 18*s.* to 20*s.* The Federation of Iron and Steel Manufacturers desired emphatically to inform the Commission that the effect of granting the miners' application or any part of it, which would materially increase the price of coal, would cripple many industries in this country and so injuriously affect the necessary exports of iron, steel and machinery as to lead to decrease in production of iron and steel and to consequent lack in employment. Mr. Talbot added that for every shilling advance in the price of coal, approximately 4*s.* per ton was added to the cost of producing finished steel, for fuel only. For wrought iron, the increase would be much greater.

Sir Daniel Macaulay Stevenson, member of the Controller of Coal Mines Consultative Committee, and head of the firm of D. M. Stevenson and Co., said that the price of export coal depended entirely upon competitive prices; exporters could not obtain more for coal in any market than the market could get from other sources. Unless we maintained our coal exports, food prices would seriously increase. In fact, everything brought to this country would be increased in price. The United States' coal production was nearly as much as the production of Great Britain and Germany together. The continuance of high British coal exports depended entirely upon whether the miner was going to produce as much as formerly in a shorter day. Sir Daniel stated he had a brother in America who told him that his wages bill was double what it would be in this country, and yet his wages bill per ton was just half what it was in this country. If our men, he added, can do something like that, we can give them far more wages and far shorter hours.

Sir Thomas Watson, Cardiff, said the leading position of this country as a shipowning and trading nation was due chiefly to the coal export trade. This trade comprised about 75 per cent. in weight of our total exports. He assumed that the miners' demands would inevitably increase the cost of coal and would thereby increase the cost of running shops and carrying on our export and import trades. It was a mistake to suppose that the quality of our coal was still superior to that of all other countries. Indian and Japanese coal had beaten us out of Eastern ports beyond Suez. American coal had beaten us out of the West Indies and was seriously threatening our trade in Brazil and the Plate. Australian and American coal were beating us out of the West Coast of South America. German coal had beaten us out of control of supply for the Danish State Railways. Native petroleum and Silesian coal had lately beaten us out of the Roumanian State Railways. Russian and Silesian coal had beaten us out of the Odessa market. Owing to the fact that America produced from 600 tons to 900 tons of coal per man employed, against 243 tons per man employed in this country, America would always be able to supply coal f.o.b. cheaper than we could. The United States coal output was now double our own.

At the sitting on 10th inst. of the Coal Commission, Mr. A. E. Bowen, chairman of the Buenos Ayres Great Southern Railway Company and chairman of Messrs. Wilson, Sons and Co., Limited, said that previous to 1914 very little American coal was shipped to South America. In 1910, America shipped to Brazil, Uruguay and Argentina 96,000 tons; in the twelve months ending June 13, 1916, the quantity was 1,619,000 tons. Our exports to the same countries had decreased from 6,304,000 tons in 1913 to 1,105,000 tons in 1916. Mr. Ridley Warham, general manager of the Ashington Coal Company, Limited, Newcastle, also gave information pointing to the increase in American competition.

Mr. A. J. Hobson, Sheffield, giving evidence on behalf of the Council of the Associated Chambers of Commerce, representing over 40,000 firms in the United Kingdom, said he regarded the production of ores in this country as the whole fount of our revenue. The question arose as to whether it was wise to press any claim, however sympathetically it might be regarded in the abstract, to the hilt at a time when our export trade was so much jeopardised. He added information on the cost of fuel on the export of high quality crucible steel and alloy steels. In 1913 the cost of producing a ton of crucible steel was 8*l.* 14*s.*, whereas in 1918 it amounted to 17*l.* 12*s.* 6*d.* Of that the cost of coal was 8*l.* 4*s.*, against 4*l.* 12*s.* in 1913, wages 6*l.* 4*s.* against 2*l.* 11*s.*, and the cost of repairs, upkeep, &c., was 3*l.* 4*s.* 2*d.* against 1*l.* 4*s.* 9*d.* Every shilling on the

price of coal cost crucible steel and steel alloy 14*s.* 10*d.* a ton extra. The cost in fuel alone of producing 1 ton of finished steel was 9*l.* 6*s.* 9*d.* in 1913 at the present time the cost in fuel alone was 20*l.* 1*s.* 6*d.*

Mr. D. Milne Watson, governor of the Gas Light and Coke Company, stated that an advance of 1*s.* per ton in the price of coal meant an advance of ½*d.* in the price of gas. On the total quantity of gas sold, this meant an increase of 500,000*l.* per year to the consumers for every shilling advance in price. Experience of Government control had not been satisfactory so far as the gas industry was concerned. Gas undertakings were worked under a form of Government audit. Though opposed, from the point of view of gas undertakings, to the nationalisation of coal, he thought the "Gas" system of audit might with advantage be adopted in the coal industry.

Sir Richard Redmayne, who gave evidence before the Commission on the 11th inst., said that under present conditions the miner spent below ground an average of 8 hours 37 minutes; deducting from this 1 hour for the time spent in travelling underground to and from his work, the time at the face was 7 hours 37 minutes. The 6-hour day would reduce the actual time spent at the face to 5 hours 37 minutes, a reduction of 26·2 per cent. in effective working time. The resulting reduction in output would be serious, but he did not believe it would be in direct proportion to the reduction in hours. The incidence of the Eight-Hour Act had not been anything like so bad as had been prophesied. Taking all points into consideration, he arrived at the figure of 21 per cent. as being the reduction in output which would result if the reduction in hours asked for by the miners were made immediately applicable. In regard to absenteeism, the mean for all underground workers was the following: 6·1 per cent. in 1899, 7·1 per cent. in 1905, 5·7 per cent. in 1913; 5·3 per cent. in 1914, 4·9 per cent. in 1915, 4·7 per cent. in 1916, 3·9 per cent. in 1917; and 5·9 per cent. in 1918, when influenza was a contributory cause. The Mine Organisation Committee expressed, in 1915, the opinion that the possible increase in output due to elimination of voluntary absenteeism would be about 14,000,000 tons per annum. Sir Richard advocated the conveyance underground by mechanical means of workmen to and from their work. In regard to mechanical coal cutters, Sir Richard stated that in 1916 there were in the United Kingdom 3,459 such machines, which yielded 26,303,110 tons of coal, whereas in the same year there were in the United States 16,197 machines and an amount of 253,295,960 tons of bituminous coal mined. In this connection, he added that the Americans probably adopted machinery more readily than men of other nationalities, but the output per machine was due to geological conditions.

Sir Richard further said that the present system of individual ownership of collieries was extravagant and wasteful, whether considered from the point of view of the coal-mine industry as a whole, or from the national point of view. He outlined a number of advantages which would result from collective production. He was not in favour—as he saw it at present—of state ownership, although he was strongly in favour of collective production.

The future of the Italian coal supply is causing grave anxiety, says the *Economista d'Italia* for February 14.

Italy will require at least 13,000,000 tons of coal annually, of which she produces barely 1,000,000 tons herself. England used to supply 75 per cent. of the coal used in Italy, but the production of coal in England is falling. In 1913 the production was approximately 260,000,000 tons, in 1915 230,000,000 tons, and in 1917–18 224,000,000 tons. In Germany, from which country Italy used to obtain about 16 per cent. of her supply, the production has fallen from about 250,000,000 tons in 1913, to 210,000,000 tons in 1915, and to probably a still lower level in the later years of the war. In Austria-Hungary the production has fallen from about 54,000,000 tons in 1913 to 25,000,000 tons in 1917. In France the production has fallen from about 36,000,000 tons in 1913 to 25,000,000 tons in 1918. The United States of America provide the exception, the production having risen from about 520,000,000 tons in 1913 to 565,000,000 tons.

It must be pointed out that the Italian Government had made demands to the Allies for 800,000 tons of coal per month, which was the minimum necessary for the country. This quantity could not be called excessive, seeing that the pre-war imports amounted to 11,000,000 tons per annum. The Allies, however, cut down the supply to Italy to 400,000 tons, which is totally inadequate. France had asked for 4,000,000 tons, and was granted 3,000,000 tons, although France has coal mines of her own, whereas Italy has none. It was hoped that this extremely difficult situation might have been relieved by importing coal from America, but we are told that this has been opposed by England, adds the Italian Journal.

It is to be hoped that the Government will take the necessary action to safeguard Italian interests.

The *Frankfurter Zeitung* for January 25 asserts that the average daily output of a coal hewer in peace time was 2·2 tons, it is now 1·6 tons; taking all the workers into consideration, the average output per worker was in peace time 1·05 tons, in December 0·7 ton, and in January 0·6 ton. Since June the monthly output in the Ruhr district has gradually sunk from 346,000 tons to 227,000 tons, and the deficit is accompanied by the exclusion of the Saar district and that on the left bank of the Rhine.

The *Hamburgischer Correspondent* for February 2 gives the following figures showing the continuous decline of Germany's coal output:—

Average monthly output in the Ruhr district:—

	Million Tons.
1913	9·54
1918, first to third quarter	8·38
1918, October	8·45
1918, November	6·25
1918, December	5·77

It is reported from Essen, in the *Kölnische Zeitung* for January 23 and 26, that the strikes in the Ruhr district, from December 2 until January 20, involved 111 shafts and 600,000 shifts in all, equivalent to a reduction in output of 450,000 tons.

The Union for the Rhenish Lignite Industry states that the output for December, 1918, shows a falling-off of 46·8 per cent., as compared with August of the same year. The manufacture of briquettes has decreased by 48·9 per cent. during the same period.

Reports of a most encouraging nature, says *The Iron Age*, New York, are coming in from manufacturers in the Central West in respect to the restoration of greater efficiency in labour. During the period of the war efficiency reached a low ebb. A workman knew that if he were discharged, or voluntarily left one job, another job was waiting for him. Consequently, incentive to effort was lacking. With the scarcity of labour, few men were turned away from the factory employment office and men largely incompetent were put to work. The two factors, lack of incentive on the part of skilled men to do a fair day's work because of having no fear of dismissal, and the placing of unskilled and incompetent men in the shops, resulted in a marked decrease in general efficiency and a corresponding increase in the cost of production.

Now conditions are greatly changed. Men capable of doing a good day's work are coming to realise that they must render the service for which they are paid, knowing that there are plenty of others waiting to take their place and that a new job is no longer easy to find. In addition, a weeding-out process is being carried out, and men who are still labouring under the delusion that they can give minimum effort in return for their wages, as well as those who are not fitted for the work, are being replaced at the same wages by more competent men. In this way, plants are again being keyed to an efficiency basis, and there is a decided increase in output with the same number of men on the pay roll, or, in other words, a decrease in labour costs without a lowering in wages.

The National Aircraft Engine Factory at Edmonton has been purchased by Messrs. Straker, Squire, Limited, automobile manufacturers, for 140,000*l.* These works cost the country 133,000*l.* to build. Inasmuch as this is the first of our National War Factories to be turned over to private enterprise for peace-time production, the conditions and circumstances of the sale are of considerable public interest. The factory is a new one, constructed within the last two years and comprises a splendid range of buildings of brick and glass standing on a site of 14 acres. The works adjoin the Edmonton passenger station, and are well equipped with railway sidings.

The purchasers propose to transfer the whole of their manufacturing activities to Edmonton. Their programme is to concentrate upon two standard models, a six-cylinder type of fast pleasure car and a four-cylinder commercial chassis suitable for transport work and motor omnibuses. The cars will be British-built throughout, and will be fitted with British magnetos. Almost all the engineering work and the whole of the body work will be completed on the premises. The entire factory will be organised on the lines of quantity production from standard jigs, and it is anticipated that 5,000 workpeople will be continuously employed. During the war, Messrs. Straker, Squire have been engaged upon aircraft engine production, and it is claimed that the knowledge thereby gained of how to combine maximum efficiency with light weight will be a deciding factor governing post-war automobile construction. According to present plans 2,000 complete motor vehicles will be produced from the converted factory within the first year of working.

Progressive firms who contemplate business expansion will be interested to know that there are 14 other national factories in various parts of the country available for private enterprise. Inquiries should be addressed to the Disposal Board, Land and Buildings Section, Embankment Buildings, Charing Cross.

ELECTRIC WELDING.*

ELECTRIC WELDING DEVELOPMENTS IN GREAT BRITAIN AND THE UNITED STATES OF AMERICA.

By JAMES CALDWELL and HENRY BAILEY SAYERS.

ELECTRIC welding within the last two years has been largely utilised to facilitate the output of munitions, and also as a means of renovating plant and machinery in addition to the carrying out of considerable ship repairs.

The retarded expansion of electric welding in the past is attributed mainly to the absence of clear understanding as to the essentials of the process and the lack of facilities to enable research investigation to be undertaken.

Successful application is also dependent on the correct design and preparation of welded structures and the provision of sufficiently skilled operators.

Electric Welding Systems.—The three methods of joining metals which employ electric current directly as the source of heat are described, and their outstanding features are emphasised. With the resistance or contact method the welding operation is rapid and efficient, besides being easily performed by unskilled labour, provided the machines are adjusted periodically. To enable repetition work to be undertaken at a higher rate of output, quick-releasing clamps and automatic switches are invariably fitted.

Metal sheets and plates joined by spot welding are placed between the electrode points of a machine. The circuit is closed, and sufficient pressure is maintained to secure intimate contact while heat is generated by the passage of current across the gap between the plate surfaces. The resistance weld thus obtained forms a connection similar to but more economical in operation than riveting, when the system can be applied with ease.

Seam or line welding is carried out by machines with mechanically-driven roller electrodes in lieu of the pointed electrodes used for spot welding.

The carbon-arc process comprises the autogenous soldering of metal with the arc of a carbon electrode. Special skill is required in manipulation, by reason of the great heat generated at the arc, and welding by this means has therefore been largely confined to work of substantial size and thickness, although the authors point out that by observing certain necessary precautions, success has been achieved in applying the process to work of a general nature, particularly where speed is important.

Reference is made to the numerous stages of development through which the metal-arc process has passed since its inception by Slavinoff, and particulars are submitted relating to the use of electrodes composed of covered and coated metal under various conditions of electric supply.

The fact is mentioned that most valuable work has been carried out in recent years with bare metal electrodes, but by virtue of the protecting properties of suitable non-conducting material, it is now universally recognised that by enclosing the arc in a molten covering, oxidation and disturbance of the crystalline structure at the weld is reduced to a minimum. Flux-covered electrodes which meet these conditions are responsible for the rapid recent advances that have been made in metal-arc welding.

Electric Supply Conditions.—Resistance methods of welding make use of alternating current with heavy current and low pressure, rarely exceeding 20 volts. Transformers are incorporated in the welding machine to minimise reactance and resistance of connecting leads. Direct current at about 90 volts is essential for carbon-arc welding. For this purpose alternating current must not be employed, owing to the necessity of keeping the electrode negative and the further difficulty of maintaining the arc, particularly with a low periodicity.

Where arc welding is carried out with bare metal electrodes, it is usual to employ about 45 volts with direct current, as alternating current has not yet been found suitable, although there are possibilities of later application.

With flux-covered electrodes, satisfactory welding may be carried out with either direct or alternating current. Dealing with the most suitable pressure for arc welding, the authors state their opinion that 60 volts direct current is sufficient to secure a good weld, but a somewhat higher voltage is found necessary with alternating current, due to the fact that the arc is more difficult to maintain at that pressure with alternating current, as the current falls to zero at each period, and a larger volume of arc gas is desirable to maintain the circuit over the zero point.

The second part of the paper deals with the general application of electric welding to various engineering and shipbuilding industries.

On railway and tramway systems the welding of rail joints constituted one of the earliest successful applications of flux-covered electrodes. To repair effectively joint connections, flanges and worn rail surfaces, both carbon and metal-arc systems have been

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* Abstracts of three papers read before the Institution of Civil Engineers, on Tuesday, March 11, 1919.

employed to advantage, while the maintenance of rolling-stock is also an important welding problem. Instances are cited of the efficiency and economy resulting from the use of electric welding in steam railway practice, including relative data regarding repairs to locomotives, the reinforcing of worn wheel flanges and car axles, the connection of boiler tubes, flue-box patches, cylinders and frames. The metal-electrode process is utilised almost entirely on this type of work, and with the recent improvements in this country of the flux-covered electrodes, some of which are specially designed for welding high-tensile and alloy steels, the scope for electric welding plant in railway shops should be increased. It is a matter of interest that the repair of cast-iron parts by the metal-electrode process is almost common practice in some locomotive repair shops in America.

In munition engineering works, resistance and metal-arc welding processes have been employed to a large extent in the production of mines, depth-charge cases bombs, &c. Instances are given where the arc welding process is applied in aircraft work, but only to a limited extent, due to the metal parts being invariably of light gauge. In view of the efficiency of an electric weld, the authors advocate the adoption of the process for aeroplane construction to a much larger extent in the future.

Electric welding should benefit the automobile industry, especially in the easy assembly of steel bodies and in the repair of special steel parts with composite metal electrodes covered with suitable composition, by which means alloy and high-tensile steel can be successfully repaired and reinforced with metal having characteristics allied to those of the original material. In this way crankshafts, broken or worn teeth of gear-wheels and gear cases can be renovated, tanks and barrels manufactured, and caulking eliminated in riveted structures.

Two methods of employing electric welding in the manufacture of tools are described, including the resistance welding of high-speed steel parts and the deposition of the cutting edges on mild steel shanks with metal-arc welding.

In shipbuilding electric-arc welding has been proved practical as a substitute for forging, riveting and caulking. Following the satisfactory conclusion of a series of tests carried out with ¼-in. ship-plate connections, certain ship structures have been assembled either entirely or in part by this means, and examples are given where the process may be used to advantage in the construction of internal fittings and superstructures. As regards the possibility of joining ship hulls and spot welding, information derived from recent experimental work indicates that spot welding of thick steel plates is capable of results equal in strength to riveting, with appreciable economy.

The remainder of the paper is devoted to a description of the following tests and experiments concerning the application of electric welding.

1. A steel tank, approximately 10 ft. cube, with bar metal electrode connections, which was built up of ¼ in. steel plates, having many different types of welds, in order to gain information as to the most suitable.

2. A series of investigations comprising the welding of ¼-in. ship plates under varying conditions. Mechanical tests were made with 23 welds, and the results, tabulated and analysed, are given in an appendix.

3. In the construction of a bulkhead door, spot welding was used for the main construction and arc welding with bare metal electrodes as a substitute for caulking. On testing, it was found that the number of spot welds could safely have been reduced by one-half.

4. Tests to determine the most efficient voltage for metal-arc welding. In view of the economy that has resulted by the use of lower voltage than standard practice in this country and the distinct advantage of low voltage at the arc in maintaining the characteristics of the metal at the weld, these investigations were undertaken under varying conditions of electric supply with flux-covered metal electrodes. It was found that with a low-voltage supply, the external appearance of the weld is a certain guide to its value, and it can safely be assumed to be free internally from slag and oxide inclusions. The results of mechanical tests are confirmed by microscopic examinations of the metal structure at the fracture.

EXPERIMENTS ON THE APPLICATION OF ELECTRIC WELDING TO LARGE STRUCTURES.

By WESTCOTT STILE ABELL, M.Eng., M.Inst.C.E.

The employment of electric welding for the carrying out of repairs has been a common practice for a number of years past, but it is only within the last two years that serious consideration has been given to the question of the extended use of this process to those parts of a vessel which are subject to important structural stresses.

In this paper a full account is given of the comprehensive series of experiments recently carried out on behalf of "Lloyd's Register of Shipping," to determine the possibility of the application of electric-arc welding to ship construction.

Information was sought regarding the physical properties of the welding and welded material, and its ability to withstand the alternating stresses to which vessels are subject.

Modulus of Elasticity.—This property of the welded material was determined under several conditions, one series of observations being taken on test specimens, which were made as large as could be tested in a 300-ton machine, with a view to approximating as closely as possible to conditions of actual service. The length of the specimen, in which an ordinary butt weld was fitted at the centre, was 6 ft. clear between the holders, while the breadth ranged from 48 in. to 22 in., depending on the thickness of the plate. The extension under known loads was carefully measured, both in way of the weld and at various points on the plain plate adjacent to as well as well clear of the weld.

Diagrams are given showing the extensions as noted at the various points, and from an examination of these it would appear that, in general, the extensions in way of the weld do not show any marked difference from those on the solid plate, the lines showing extensions in way of the weld lying among the others, without disclosing any distinctive features.

To confirm this result a set of specimens of normal test-piece size was made, from some of which automatic stress-strain diagrams were obtained, while in others readings were taken with a Ewing extensometer. The results obtained showed the same general characteristics as those from the strain-meter readings on the large specimens, and appear to confirm the inference that there is very little difference between the modulus of elasticity of the welded material and that of the solid plate.

Similar tests were also carried out on small test-pieces composed entirely of deposited metal, from which it appeared that the value of the modulus of elasticity of the material actually forming the weld was 11,700 tons per square inch.

Ultimate Strength and Elongation.—In the case of butt welds it was found that the tensile strength of the joints was 90 per cent. to 95 per cent. of that of the solid plate.

As the most common form of joint used in ship-building is the ordinary overlap, a complete series of tests was carried out on welded joints of this form. The tensile strength of the joint varied with the thickness of the plating, and was 65 per cent. to 85 per cent. of the strength of the solid plate in cases where a full fillet was fitted on both edges of the lap. The corresponding figures were practically the same in cases where a full fillet was fitted on one edge and a single run of weld on the other edge. In a comparative test the strength of a treble-riveted lap joint with plates ¼ in. in thickness was found to be between 65 per cent. and 70 per cent. of the solid plate.

Elongation.—As is well known, the ultimate elongation of a welded specimen is considerably less than that of a plain plate, and in this series of tests was found to be only 8 per cent. on a length of 8 in., as against 29 per cent for the solid plate, while the contractions of area were 7 per cent. and 45 per cent. respectively.

Alternating Stresses.—The author points out that it is of primary importance in shipbuilding that welded joints should be able to withstand the alternating stresses to which the structure of a vessel is subjected, and, consequently, that special attention was paid to the determination of the properties of welded material under alternating stresses of known value. Two types of apparatus were employed in these tests, in one of which the specimens were in the form of bars, while in the other flat plates were used.

In the first type the bars, which were 3 ft. in length, with a weld 9 in. from one end, were fixed in the grip of a lathe at one end, and were loaded at the other end, and at an intermediate point with weights of known amount. This arrangement produced a uniform bending moment with consequent calculable stress on the material of the rod over that part of the bar which contained the weld.

The lathe ran at a speed of 1,060 r.p.m., and the stress on each part of the material was changed during each revolution from compression to an equal stress in tension. The bars were tested in pairs, one welded and one plain, at varying stresses, and curves are given showing the number of revolutions endured by the various bars before fracture, from which it may be inferred that the highest stress at which the welded bars are able to withstand a very large number of repetitions of alternating stress is about 6 tons per square inch, the corresponding figure in the case of the unwelded bars being about 10 tons per square inch.

In the second form of apparatus, the specimens, flat plates 14 in. by 5½ in., were held firmly in clamps at each end and at an intermediate point near the centre. The end clamps were fixed in position and the centre clamp by means of a crank-arm was caused to oscillate and to bend the specimen equally up and down by adjustable amounts, the maximum total movement in any of the experiments tried being ⅞ in. on a length of 12 in. The specimens were arranged in sets of four, namely, plain plate, butt weld, riveted joint and lap weld, and the number of repetitions at which each specimen parted was observed.

The curves showing the results of these tests would appear to indicate that the stress at which the specimens with butt weld are able to endure a large number of alternations is about 70 per cent. of the stress borne by the similar plain plate, the corresponding figure for the comparative endurance of lap welds and riveted laps being about 60 per cent.

Bending.—The results of the bending tests show that the welds do not compare very favourably as regards bending with ordinary mild steel, the angle at which fracture occurred varying from 80 deg. with ¼-in. plates down to 20 deg. with 1-in. plates.

Crushing.—To ascertain the capability of welded material to resist the shear stress induced during crushing, specimens having the weld at an angle of 45 deg. to their axis, together with corresponding unwelded samples, were tested under compression. Both welded and plain specimens yielded by bending before crushing took place, but the welded specimens withstood the compressive load as satisfactorily as the others.

Chemical Analysis.—From a chemical analysis of the ordinary steel plates, of the metal of the electrode, and of the material in the weld, it appears that the electrode was of very similar composition to mild steel, but that the carbon manganese and were almost oxidised away from the filling-in material during the process of welding the deposited material being practically pure iron.

Microphotographs.—The author has added to the value of the paper by including a series of microphotographs showing the structure of the material in the vicinity of the welds. One of these photographs is particularly interesting as presenting a complete picture of the change which takes place between the ordinary mild steel plate unaffected by the heat of the welding and the deposited material, the alterations in the structure being very clearly defined.

These photographs show that there is a gradual diffusion between the original and the added metal without any abrupt line of demarcation, the joints thus conforming with one of the chief requisites for a sound junction.

It may also be inferred from the photographs that the distance from the welded surface within which the structure of the original metal is appreciably disturbed by the heat is only about $\frac{1}{10}$ in., and may be even less in thinner plates.

THE APPLICATION OF ELECTRIC WELDING IN SHIP CONSTRUCTION AND REPAIRS.

By JOHN RENEY SMITH.

The author points out that the ease with which a high temperature can be produced at any required spot by the electric current led to the adoption some years ago of electric welding on the system introduced by Mr. Bernados, which employs the heating power of the electric arc. The method of using the heat was quite simple, an ordinary electric-light carbon being secured in a special holder through which passed an insulated conductor carrying the current to the carbon. The carbon was connected with the positive main from the generator, and the metal to be heated was joined to the negative main. The carbon was first put in contact with the metal near the part to be welded, and then drawn a short distance away, when the electric arc was struck and the metal was quickly heated. The arc was 4 in. to 4½ in. in length. In about 12 seconds the required temperature was produced, the arc was removed and the weld was hammered in the ordinary way. The current employed was about 150 amperes at 70 volts.

The use of carbon proving unsuitable for boiler work or for any part of a structure subject to heavy stresses, Pommee, of Hamburg, introduced the system that is now generally followed. The principal feature of this method is that the iron welding-pencil forms one pole and the part where the welding is to be done the other—an innovation that makes possible a perfect condition for carrying but many intricate operations. Another advantage of the process is the avoidance of great heat and the consequent physical distress occasioned to workmen operating in confined spaces. The extremely high temperature of the electric arc rapidly brings to a welding heat the small point being dealt with; the point of the iron pencil simultaneously rising to the same temperature, when a drop is deposited upon the work and combines with the metal heated to receive it. The drops from the welding pencil follow one another in quick succession until the space is filled and the work completed. Although the temperature produced is a 3,500 deg. C., it is reached rapidly, and the work is finished before the heat has been transmitted to any great extent to the surrounding metal.

Descriptions and illustrations are given of typical repairs that have been successfully carried out under the author's supervision, and for which considerable economy in money and time is claimed, inasmuch as the necessity for renewals was obviated.

The success of this system of uniting metals has encouraged the idea of substituting it for the present method of riveting in the main structure of sea-going vessels, as great saving in material would result if plates were butt-welded instead of lap-jointed or strapped, and in any case marked economy of material would result from eliminating rivets to a large extent, if not entirely. Extensive tests in the application of arc welding to ship construction carried out at a Government dockyard on plates ¼ in. to 1 in. thick have given very satisfactory results.

In experiments carried out by the author all the tests applied were for cross-bending and tensile stress, whereas he is of opinion that fatigue tests should also be made and examined. "Lloyd's Register of Shipping," after exhaustive investigation in this direction, and into the effects of vibration on welded joints has, in conjunction with the British Corporation and the American Bureau of Shipping, recently issued an extensive list of work in which electric welding may be applied on vessels "classed" by them.

The author points out that the secret of success in electric-arc welding being largely in the hands of the operator, very careful inspection is essential to good results and to progress in this new method of construction.

"PARAGON" THERMO-ELECTRIC SHIP PROPULSION (PATENTS).—Mr. William P. Durtnall, inventor and patentee of the above system of ship propulsion, and speed reducing from high speed prime movers such as steam turbines or internal-combustion engines to ships' propellers, has asked us to mention that certain patent specifications have been, since 1912, sold by the Patent Office Sales Department (inadvertently) not bearing the official stamp. Recently, whilst travelling in France, he came across such an unstamped document. Mr. Durtnall, on his return, immediately took steps to draw the attention of the Comptroller-General to this error, and that official has acknowledged the matter by issue of an officially stamped and signed document, a lithographic copy of which we have examined; the patent referred to was No. 19903/1911, applied for by a Swedish firm.

THE STANDARDISATION OF RAILWAY WAGONS.

THE tenth meeting of Leeds Centre of the Institution of Locomotive Engineers took place in the Philosophical Hall, Park-row, Leeds, on Tuesday, February 25, Mr. H. N. Gresley in the chair. Mr. Gresley regretted that Mr. J. R. Bazin, whose paper on "Suggestions for Standardised Wagon Designs for British Railways" was to be read, was unable to be present owing to illness, and in his absence the paper was read by Mr. Houldcroft, the local secretary.

Mr. Bazin's paper commenced by stating that uniformity in the design and capacity of the wagon rolling-stock of British railways was among the many reforms shown by the war to be necessary, and went on to point out that from the earliest days each company has designed its own peculiar type of vehicle, while private firms have also been required to provide wagons for their own and other traders' use. He also dealt with the wasteful system in use prior to 1917, of returning wagons to the owners empty, which practice was considerably reduced by the introduction of the "common user" arrangement in January, 1917.

The advantages of standardisation were outlined from a practical and also a military standpoint, and also from the point of view of the builder, user, and repairing of the wagons.

The types of wagons selected for standardisation were five in number, as follow :—

1. Twelve tons open wagon with high sides.
2. Twelve tons open wagon with medium sides (to fall).
3. Twelve tons open wagon with low sides.
4. Twelve tons covered wagon.
5. Twenty tons open wagon for coal.

The 12-ton capacity wagon was to be preferred for four of the types on account of its being possible to keep dimensions within reasonable limits, while it can be handled in the shunting yards, warehouse docks and sidings with equal ease. An important point in favour of 12-ton wagons is the advantage gained in carrying capacity as compared with 10-ton wagons, without a corresponding increase in tare weight.

The 20-ton coal wagon is included because it seems advisable that a wagon of this type should be standardised for the conveyance of locomotive coal, as most collieries are now able to deal with them. The four types of 12-ton wagons can all be constructed with the same wheels and underframe, but the 20-ton wagon would need another design of slightly increased dimensions on account of its greater carrying capacity.

Mr. Bazin dealt exhaustively with the leading dimensions of the various wagons selected for standardisation, these dimensions being governed by the loading gauges of the various railways. Under the prevailing conditions the maximum dimensions must not exceed the minimum gauge of each individual railway. The constructional details were also gone into, the question of steel *versus* wooden wagons being commented upon.

In conclusion, Mr. Bazin stated that the advantages to be derived from standardisation of wagons cannot be over-estimated, and the present time, when reconstruction is the order of the day, is the most opportune to bring it about. There should be no delay on the part of the different railway companies in adopting the principle, as both from a manufacturing and economical point of view, as well as from a national aspect, the sooner it is put into operation the better, and the sooner will come the day when the many variations of wagon designs will have disappeared from our railways.

Mr. Gresley pointed out that in general the paper sets out the experience of many years in the maintenance of railway wagons, and the author had dealt very fully with the advantages of standardisation, but in order to get the best results it will be necessary to standardise the various railway loading gauges.

Standardisation, he said, would give an increased carrying capacity, with a saving in tare weight, and the width of our wagons could easily be increased to give that extra carrying capacity. With the extra width, the length could be decreased, which was a great point because of the length of sidings.

A matter of considerable importance, in Mr. Gresley's opinion, was the relation between the carrying capacity of a wagon and the load carried in this country, the average load being far below the average capacity. This means that wagons are made strong enough to carry, say, 12 tons, or 20 tons, and yet are never called upon to carry these loads, the result being a waste of material in the construction of the vehicles and a considerable waste of engine power in hauling unnecessary tare weight. Mr. Gresley also spoke at some length on the question of private owners' wagons, there being, he said, a considerable loss involved in sorting out and returning these wagons empty to the collieries and to owners. He strongly advocated a common pool for all wagons, which would be one of the first results of the nationalisation of railways if that should ever come about.

Mr. Dow said that from a railwayman's point of view the wagon question was one of primary importance. In his opinion the war had brought before our notice the great need for standardisation in everything appertaining to the wagon world, though it is hardly to our credit that a war has been necessary to bring home to us this fact. In Mr. Dow's opinion it will hardly be possible for the whole of the traffic to be carried in the five types of wagons proposed by Mr. Bazin, but possibly other types were looked upon as special wagons, suitable only for special traffic—that is, for perishable goods, insulated and other types.

The 17-ft. frame which Mr. Bazin had brought to notice is the length of frame adopted by the North-Eastern Railway for their open goods and other wagons, so that the North-Eastern Railway Company had been standardising their wagons for some considerable time.

Mr. Kitchen said Mr. Dow had practically covered his ground, but he (Mr. Kitchen) spoke on the question of the uniform load gauge, instancing the North-Eastern Railway dimensions, and on the subject of wagons for special traffic. He agreed with Mr. Gresley in regard to the relation between marked and actual carrying capacity, that is the capacity actually utilised in practice on our railways.

Mr. Duncan Bailey referred to the fact that for a good long time he had been an advocate of standardisation, and discussed the whole subject from the point of view both of the private builder and of the private owner. He considered that more steel should be used, the primary objective being the utilisation of home resources, as we had steel here but not timber in sufficient quantities. He spoke not only on the general policy, but dealt very thoroughly with many of the leading details, and suggested the appointment of a committee.

Mr. Thorpe went into the matter from a traffic point of view and also discussed the question of carrying capacity, which, he said, could be increased by adding to the height of a wagon instead of the length, and so reduce siding length. Traffic officers keenly appreciated all such efforts as those of Mr. Bazin's on the practical points of standardisation, and he knew of no officer on the North-Eastern Railway who did not welcome such endeavours.

Mr. Rowntree went generally into the question of standardisation, the need for which, he pointed out, had been realised before the war in some countries, if not by British railways. He gave instances of standardisation from the manufacturer's point of view, showing on the screen a type of wagon for which certain works were cut out to deal with quickly, thus ensuring a better delivery than could be given if the wagons were not standardised.

Mr. Houldcroft said Mr. Bazin had not spared himself time or energy, and he was sure no one would be better pleased if the result of this discussion was a standard wagon of high carrying capacity. The chairman had always urged the importance of the reduction of tare weight. He considered that Mr. Bazin's suggestions were to suit existing conditions. These conditions had for thirty or forty years dictated the type of wagon which had been so supplied, and it is now contended that because there are so many thousands of these types, therefore conditions could not be altered. He maintained that the result of following the conditions was a multiplication of varied types, and asked "Are the conditions unalterable?" He further suggested the removal of anything which interferes with a railway and its efficiency as a first-class freight carrying machine. He maintained that with high capacity modern wagons, on a total freightage of 600,000,000 tons per annum a saving would be possible of 20,000,000*l.* per annum, which, capitalised at 5 per cent., would justify an expenditure of 400,000,000*l.* sterling.

Quoting Mr. Thorpe's former speech, "A little experience is worth a deal of theory," Mr. Houldcroft had a vast experience, and upon lines where the rolling-stock was in his charge, after a searching investigation, wooden wagons were condemned for renewal after twenty-five to thirty years, steel wagons thirty-five to forty years, and with such steel wagons in busy seasons he had records of only 2 per cent., and at times 1 per cent., under repairs at one time. Could any English line show such a record? No special appliances were found necessary at out-stations. He furnished many statistics concerning English and foreign railways, and claimed that the vital interests of the country demanded further inquiry. A committee of experts should be appointed to deal with this matter.

SUSPENSION OF THE AMMONIA CONTROL ORDER.—The Minister of Munitions has suspended the Ammonia Control Order. Until further notice, therefore, it will be permissible to manufacture and trade in ammonia and the products containing ammonia without obtaining a licence from the Ministry.

CONTACT BOWS OF CARBON FOR ELECTRIC VEHICLES.—When copper became scarce in Germany during the war, the contact bows for aerial railways were replaced by aluminium, which had been used for this purpose before the war already. Aluminium then became unattainable, however; thus zinc came into use, but it did not answer particularly well. At the Immigrats plant of the Rhenish-Westphalian Electricity Works experiments were then made with contact pieces of carbon. At first the wear was 1 gramme of carbon per 10 car-kilometres; that figure was soon improved upon, however, and the wear went down to 1 gramme per 67 car-km. The zinc bows did not last more than 8,000 car-km., and the average for aluminium was 11,000 car-km., according to D. Strojohann (*Zeitschrift für Kleinbahnen*, 1918); by autumn, 1918, some of the carbon bows had reached a life of 110,000 car-km., the average being 75,000 car-km. The carbon was first greased, but that was found to be unnecessary. The bows have a length of about 1 m., and as made by C. Conradty, of Nürnberg, they are built up of sections of carbon. The whole is mounted on a flat strip of steel plate, which is turned up on both sides so as to grip the carbon pieces; bars of cast-iron are interposed between the carbon and the steel edges so as to secure good contact. In cross-section the carbon is not solid, and a tension device, adjustable by means of screws, is fitted into the hollow to press the carbon against the holder. There is less sparking than with aluminium bows, and worn-down carbon sections can be renewed so that the carbon of the whole length of the bow is utilised.

GERMAN SHIPBUILDING AND SHIPPING.

THE following is an extract from a letter sent by the Shipbuilding Committee in Hamburg to a firm of engineers which applied to them for orders: "We consider it our duty to draw your attention to the fact that the present position of the yards offers no chance of employment whatever, worth mentioning. The present work in the hands of the yards is so insignificant, that it hardly offers a possibility to place orders beyond what has been customary to outside concerns. But even if conditions should alter, and even if this should lead to the full employment of the German yards, the number of sub-orders which may have to be given to others will be so insignificant, compared with the number of works applying for such orders, that individual works would grossly deceive themselves if they reckoned upon future ship contracts as a factor in their working plans."

The Howaldt concern in Kiel shows a surplus for last year of 618,664 marks, against 1,103,946 marks for the previous year, and the dividend was fixed at 5 per cent., against 8 per cent. for the previous year. The increase of the capital from 7,000,000 marks to 10,000,000 marks had been completed, resulting in 394,553 marks having been added to the reserve fund. The supply of raw materials had improved, but the labour troubles had increased.

If the shipbuilding industry does not appear to be in a very good way, the shipping trade is in a still worse plight. The last balance-sheets of the large shipping companies date from December 31, 1913, since which date no more reports have been published, and the Hamburg South America line and the Kosmos line have again obtained permission not to publish any balance-sheet for last year. The financial position of the companies must, of course, have suffered seriously. Added to the increased pay to their employees, which according to the wish of the authorities has been given during the war, comes the interest on debentures, which during the last peace year amounted to 3,150,000 marks for the Hamburg-America line and 2,980,000 marks for the North German Lloyd. The two expenses aggregate about 15,000,000 marks for each company, without providing for any amortisation. On the other hand, the shipping companies have derived a material influx of funds under the Act of November 7, 1917, but these funds, estimated at rather more than 250,000,000 marks, up till March 31, 1918, have hardly improved their actual financial position, inasmuch as they were meant to compensate for vessels which had been lost or seriously damaged through actions of foreign Governments, and for harbour dues and pay to the men of such vessels which, owing to the war, were retained in foreign ports.

CALCIUM CARBIDE ORDER.—The Minister of Munitions has announced that the Calcium Carbide Order of September, 1917, is suspended. Until further notice, therefore, it will be permissible for traders to deal freely in calcium carbide without a permit from the Ministry.

TIN PLATE PRICES.—The Minister of Munitions has given notice of the following increase in the maximum price of tin plate for home sales as from the 1st inst.: Coke tin plate, I.C., 20 × 14, 112 sheets, 108 lb., 33*s.* 10½*d.* Basis, per box, net, f.o.t. at makers' works.

CLAY IN ITS RELATION TO PILES.—At a meeting of the Society of Engineers, on Monday, March 10 (Mr. W. Noble Twelvetrees, president, in the chair), a paper was read by Mr. Alfred S. E. Ackermann, B.Sc.(Eng.), recording the results of 95 experiments, some taking 40 hours each, made with clay during the period December, 1917, to February, 1919. The original object was to determine the relationship between the horizontal pressure and the depth at any given point in clay, the method and its theory having been devised about a year before, December, 1917. The main series of tests were conducted by forcing into the clay various bodies representing tapered and parallel piles, some with a blunt and others with a pointed end, and in some of the experiments thin discs of metal were forced into the clay. Observations were made of the conditions attending each test, and the results are fully discussed in the paper. Among the general conclusions which appear to be justified by the qualitative and quantitative results of the experiments are the following: Clay containing a definite percentage of water, and at a definite temperature, has a definite pressure of fluidity, and when this pressure is reached and maintained the clay yields indefinitely as a dense viscous fluid, unless it be restrained from flowing, or caused to rise so as to produce a statical head of clay. The pressure of fluidity is greater when the percentage of water is less, or when the temperature is lower and *per se* is independent of the depth and depends solely on the percentage of water in the clay and the temperature in the clay. For equal depths, tapered piles support a larger load per unit volume of the pile than piles having parallel sides, the reason being that as their surfaces keep in more intimate contact with the clay, the friction on their sides is greater. The action of the point of a pile is to cause the pressure of fluidity to be attained on its surface, whereupon the clay flows out of the way. When forcing a disc into clay, the sides of the hole do not crush in (unless a certain critical depth be attained) because the pressure of fluidity of the clay having been attained immediately under the disc, the clay flows laterally, but the moment it has escaped from beneath the disc, the pressure is reduced to the statical pressure corresponding to the local head of clay, and when this is less than the pressure of fluidity the clay does not flow into the hole made by the disc, but, if the penetration of the disc be carried far enough, then ultimately the statical head of the hole near the bottom will crush in.

THE PURCHASE AND SALE OF MERCHANT VESSELS DURING 1918.

DURING 1918 the purchase and sale of trading vessels in this country, both as regards number and value was an extremely large one, including both the purchase of foreign vessels added to our mercantile marine and the sale of British vessels from one set of owners to another, both of whom presumably benefitted by the transfer. The total number of vessels which changed hands was 808, including 88 steam trawlers, 8 motor vessels and schooners, a number of dredgers, and 48 schooners and sailing vessels. As regards British vessels bought and sold the aggregate gross tonnage was 837,673 tons, and the value 26,110,000*l.*, equal to an average value per ton of 31*l.* The foreign vessels acquired during the past year had a total tonnage of 406,199 tons, for which we paid 24,163,000*l.*, equal to an average price per ton of 59*l.* These figures may be summarised as follows :—

	Tons.	Value. £
270 foreign vessels bought	406,199	24,163,000
538 British vessels bought	837,673	26,110,000
Total	1,243,872	50,273,000

The British vessels bought and sold may be subdivided thus :—

	Vessels.
Under 500 tons	267
From 500 tons to 1,000 tons	46
From 1,000 tons to 2,000 tons	28
From 2,000 tons to 3,000 tons	53
From 3,000 tons to 4,000 tons	83
From 4,000 tons to 5,000 tons	43
From 5,000 tons to 6,000 tons	10
Over 6,000 tons	3
Total	538

Beverley, Selby, Aberdeen, Glasgow and Shields found most of the steam trawlers; a few came from other East Coast ports. Of the British vessels which changed owners 322 were launched during the present century and 216 during the last one, as shown in detail by the following schedule; some of them sixty and more years ago :—

	Vessels.
From 1910 to 1918	167
From 1900 to 1910	155
From 1890 to 1900	122
From 1880 to 1890	48
From 1870 to 1880	36
From 1860 to 1870	5
From 1850 to 1860	5
Total	538

Age is obviously no bar to the saleable value of a vessel when the demand exceeds the supply; scores of steamers must have been scrapped during the last two decades, which would now have found eager buyers at prices which would have startled their owners. Steamers generally grow obsolete long before they are worn out.

Vessels purchased from abroad and added to our mercantile marine may be grouped under three heads: (1) Those sold by European nations; (2) those obtained from Asiatic owners; (3) those acquired from American Committees.

The three northern nations—Denmark, Norway, and Sweden—sold us no less than 62 of their trading vessels, and obtain most remunerative prices for them; in many cases exceeding 80*l.*, 90*l.*, and even more per ton.

Danish.—Denmark sold us 14 vessels, of which 12 were under 500 tons, including several steam trawlers. One large steamer exceeded 6,000 tons. The aggregate tonnage was 12,422 tons and the amount we paid 914,500*l.*, equal to an average of 73*l.* per ton, an extremely high one. No less than 11 of these vessels were modern, having been launched during the present century; a great contrast to many of those bought from other nations. The number of old vessels bought from abroad during the last three years must be very great, we probably now own most of the world's old vessels; their owners everywhere have been eager sellers, and we more than eager buyers. Ten of these Danish vessels were built in this country.

Swedish.—Seven Swedish steamers were purchased last year, of which 4 were under 500 tons; the aggregate tonnage was 5,264 tons, and the total purchase price 215,000*l.* Five of these vessels date from the last century, several being of venerable age and most of them are of foreign build.

Norwegian.—No less than 41 Norwegian vessels were purchased by us last year, with an aggregate tonnage of 61,306 tons, costing 5,127,500*l.*, equal to the splendid average of 83*l.* per ton. Of these vessels 8 were less than 500 tons, 6 between 500 tons and 1,000 tons, and 4 over 3,000 tons; one of them exceeded 7,000 tons. No less than 18, nearly half the number dated from the last century, 4 from the 1870–1880 decade, and 7 from the 1880–1890 decade. Of these vessels no less than 16 were built in this country.

Dutch.—Last year we purchased 10 Dutch vessels at an outlay of 1,160,000*l.*, and having an aggregate tonnage of 19,755 tons, equal to 58*l.* per ton; including several small sailing vessels of very limited tonnage; 2 small steamers under 500 tons; a dredger and a large steamer just under 7,000 tons. Excepting one of the small sailing vessels, they were all launched during the last eleven years and are all modern, serviceable vessels, of which two were built in Glasgow and the others in Holland.

French.—Eleven French vessels have been acquired during 1918, including 2 below 200 tons, one of them a sailing vessel, all the others, with one exception, were below 2,000 tons. Three were built during the war, whilst six date from the last century, one of them being over forty years old; several were built in this country. The aggregate tonnage is 13,000 tons, the amount paid 811,000*l.*, and the average 62*l.* per ton.

Russia.—A large number of Russian vessels have been added to our mercantile fleet, no less than 11 steamers and 1 sailing vessel, with one exception all built in Great Britain. Seven have been at sea since the last century, one dating from 1877 and another from 1885. Several of them are of large size, one over 7,000 tons, another over 6,000 tons, and one over 5,000 tons. The aggregate tonnage is 37,000, the cost was 1,899,000*l.*, and the average was 51*l.* per ton, a very remunerative one for Russian owners.

Spanish, Portuguese, Roumanian, Greek, Italian and others may be grouped together; in all we have purchased 11 vessels from them, several, including a steam trawler, being of small tonnage. No less than seven were built during the last century, and all except two were launched in British shipbuilding yards, so that these nations have been able to clear out a number of their older vessels, and in due course will be able to replace them with up-to-date trading vessels. The aggregate tonnage is 20,309 tons; the amount paid no less than 874,000*l.*, whilst the average is the respectable amount of 43*l.* per ton. Summarising the additions to our trading fleet due to the purchase of vessels belonging to European nations during last year, we get a total tonnage of 169,056, no less than 106 vessels, and an amount paid of 11,001,000*l.*, or an average per ton of 65*l.*

As regards Asia, we purchased both Japanese and Siamese vessels, 29 in all, of an aggregate tonnage of 70,574 tons, paying no less than 4,588,000*l.* for them. Most of them are of large tonnage, 12 being over 3,000 tons and 8 under 1,000 tons. Of these steamers, 15 were built in this country and 11 in Japan. No less than 16 were built during the last century, but 7 date from the war years.

America.—During last year we purchased a large number of vessels from both North, South and Central America, including Mexico, the Argentine Republic, Uruguay, Brazil and Chili. The total number of vessels was no less than 119, of which 47 dated from the last century; the aggregate tonnage was 154,759 tons and the amount we paid 7,905,000*l.*, giving an average of 64*l.* per ton.

Those purchased from the United States numbered 68, of which 12 were schooners and sailing vessels. The aggregate tonnage amounted to 111,190 tons, and the total value was 4,694,000*l.* Eight of these vessels were built in this country and the others in the States—they may be scheduled as follows :—

	Vessels.
Under 500 tons	17
500 tons to 1,000 tons	17
1,000 tons to 2,000 tons	17
2,000 tons to 3,000 tons	7
3,000 tons to 5,000 tons	6
5,000 tons to 8,000 tons	4

Of these vessels 29 date from the last century; no less than 8 from the decade 1870–1880, one still older, and nine from the decade 1880–1890. With one exception all those purchased from Brazil and Mexico were launched this century.

For the purpose of comparison it may be of interest to add some details of the sale and purchase of trading vessels during 1917 :—

The total number was 1,248, including 180 sailing vessels, 562 were foreign vessels bought and added to our mercantile marine, of these no less than 257 were old vessels launched during the last century—quite a large number before 1875. During the two years 1917–18 we have purchased no less than 832 foreign vessels; there can be very few left. We must now own a record collection of fossil trading vessels bought on splendid terms for the sellers, who must regret that the supply is practically exhausted. Of those acquired during 1917 no less than 188 came from the United States; 45 from Japan and 151 from Norway, Sweden and Denmark.

THE INDUSTRIAL DEPRESSION IN GERMANY.

NOT only are the German official statements marked by increased pessimism, but the reports from the various industrial centres and concerns show how completely matters have been reversed since the very substantial war profits of a year or two ago were announced. The large Gelsenkirchen Company reports that the conditions during the last few months of 1918 had been particularly unfavourable, owing to the usual complaints of shorter hours, higher wages and consequently reduced production, coupled with very serious transport difficulties. Matters have not mended during January and February; in fact, strikes at the mines and increased cost of production have further enhanced the difficulties in this department. Added to these adverse circumstances the large Adolf Emil Hütte works, in Luxemburg, and the Rote Erde concern in the district occupied by the Belgians, are temporarily outside the control of the company; they are both being worked on a very limited scale, according to what has been ascertained. The previous year's dividend of 12 per cent. will no doubt have to be materially reduced.

The Rhenish Metal Works are unable to pay any dividend for last year, whereas the company, for the year 1915–16, paid a dividend of 18 per cent. on the ordinary shares and 20 per cent. on the preferred shares, besides 100 marks bonus per share, and for the third year of the war the same dividends were paid and a bonus of 80 marks per share, making the dividends respectively 26 per cent. and 28 per cent. The company has had to contract a very heavy bank credit.

At the Rhenish Steel Works, Duisburg, the production of pig-iron and steel has fallen from, respectively, 45,000 tons and 57,000 tons in October, to respectively 22,800 tons and 28,000 tons in January. On the other hand, the wages have risen from an aggregate of 2,270,000 marks in November to 3,042,000 marks for December and 2,927,000 marks for January. This means, per ton of raw steel produced, 43·50 marks for wages and gratuities for October and 128 marks for January. In the year 1913–14, the last year before the war, wages, with a production of 697,000 tons, amounted in the aggregate to about 11,000,000 marks, or 16 marks per ton of raw steel produced; that is exactly one-eighth of the present figure. Matters are likely to grow worse during the forthcoming months. The company cannot stand this continuous loss of millions of marks per month for an indefinite period, and even with the abnormally high prices now ruling for iron and steel products, the insane increase in the cost of production cannot be covered. Besides, the company has several old contracts running and not yet delivered, which are not affected by the recent rises in the quotations.

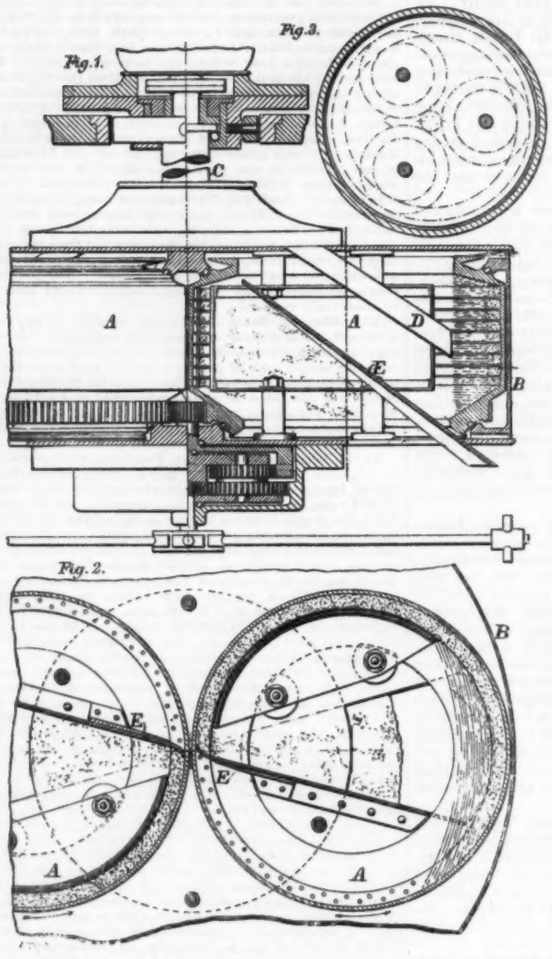
At the Mansfeld Mining Company (copper) matters are very bad, from October 1, 1918, to January 20, 1919, the sale amounted to 20,000,000 marks, whilst the expenditure amounted to 47,000,000 marks. As a result of the present state of labour, &c., the cost of production of copper amounts to 700 marks per 100 kg., or double the price of American copper. A report expresses the regret of the company at the workmen closing their eyes to the glaring facts, and unless a change somehow takes place a catastrophe is unavoidable, which will also be felt by the 80,000 hands dependent on the mining.

Berlin industries complain of the exorbitant wages demanded by the hands employed in the Berlin metal industries, and many now order their goods from outside works; in the foundry industry some hands receive 2·50 marks to 2·80 marks per hour, against 1·25 marks at Nieder Lausitz.

THE BELGIAN IRON INDUSTRY.—The Providence Iron Works, the plant of which comprises five blast furnaces will, according to what has been stated, be able to start one of their blast furnaces in some six to twelve months' time. The Cockeril Company, with seven blast furnaces, expects to have two in operation within a few weeks and four more in the course of four to six months. At the Ongrée-Marihay works (eight blast furnaces) four have been destroyed; at the Ongleur works (four blast furnaces) two will soon be in operation, and three blast furnaces of the Sambre-et-Moselle works are expected to be ready for use in the course of some three months, if the necessary raw materials can be promptly secured.

THE CHAIR OF TEXTILE TECHNOLOGY, MANCHESTER.—The Manchester City Council, at its meeting on the 5th inst., approved the appointment of Arthur James Turner, M.A.(Cantab.), B.Sc.(Lond.), to the Chair of Textile Technology in the College of Technology, Manchester. Mr. Turner had a distinguished career at Gonville and Caius College, Cambridge, where he studied natural sciences and mathematics, obtaining first-class honours in the Natural Science Tripos, Part I, 1910, a second-class in the Mathematics Tripos, Part I, 1911, and first class in the Natural Sciences Tripos, Part II, 1912. During the latter part of 1912, he was engaged in research work in organic chemistry at Cambridge under Professor Pope. He later accepted an appointment upon the scientific staff of the National Physical Laboratory, where he was chiefly engaged in research work on fabrics and dopes for aeronautical purposes. Following this he was appointed to the charge of the Fabrics Laboratory of the Royal Aircraft Establishment, where he has been engaged on a number of investigations of textile problems, chiefly from the physico-chemical point of view. Mr. Turner was also engaged upon researches involving the study of the differences of spinning and doubling twists throughout a complete range of the various materials used in the manufacture of yarns and fabrics, and for cotton in particular.

CONTINUOUS CENTRIFUGAL SEPARATION MACHINES.



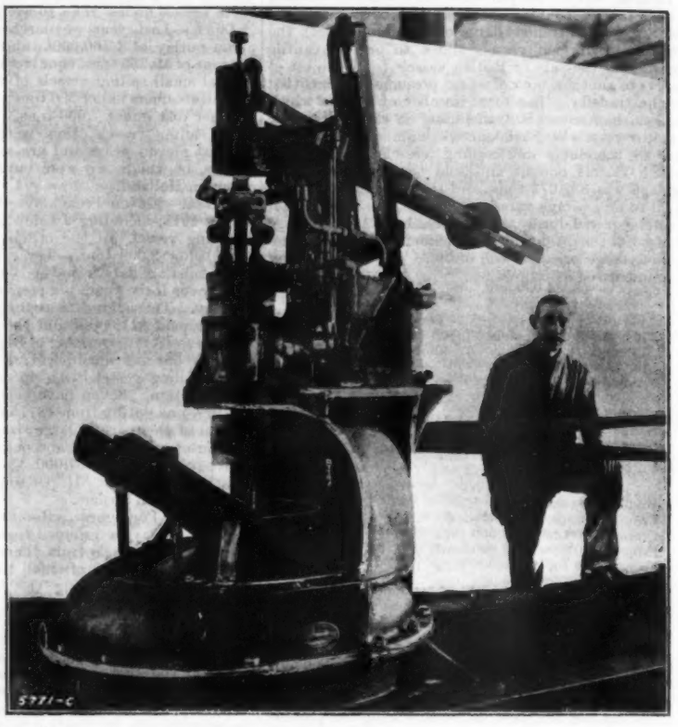


FIG. 4.

A SOUTH AFRICAN FIRM, Continuous Centrifugal Separators, Limited, has succeeded in obtaining the continuous separation of solids from liquids, and of crystalline particles from colloidal slime, by centrifugal force. We gather much of the following information concerning these machines from an address by Mr. E. J. Way, Memb. Council Inst. C.E., M.I.M.E., F.I.C., &c., at Johannesburg.

Figs 1 to 3 illustrate the "Planetary" machine which consists essentially of two bottomless buckets or vertical cylinders, A, revolving rapidly in a frame, B, around an upright spindle, C. Each of the two buckets has an independent revolution on its own axis. The pulp, or slime, to be separated is fed into each bucket against its outer wall by a shute, D, *i.e.*, at the point farthest from the central spindle. The centrifugal force generated by the revolution of the whole frame packs the solid matter of the pulp against the wall of the bucket, the fluid flowing over the upper rim and carrying the colloids with it. If desired, by lengthening the time of separation, both crystalline and colloidal solid matter are packed against the side of the bucket, and only a clear liquid is discharged over the rim. The slow revolution of the bucket continually carries away the clean and dry solids packed against its wall from the point of feed, so that a fresh face is constantly exposed to the feed flow. The packed solids are carried around in the bucket until they arrive at the inner wall, or at the point next to the central spindle. Here the centrifugal force, which at first packed them against the wall, exercises a reverse effect and disengages them with the aid of a plough, E, so that they fall down and out into any convenient receptacle. The revolving part of the machine is 3 ft. 6 in. in diameter; the machine is capable of treating over 25 tons of dried material per 24 hours.

A machine of this type was manufactured early in the war by Messrs. Duncan Stewart and Co., Limited, Glasgow, for the Zaaiplaats Tin Mining Company, Limited, Transvaal, and until the embargo on high-grade steel stopped the manufacture of spare parts for the gear, this machine was in successful use in the separation of the very fine crystalline matter carrying tin out of the hitherto untreatable colloidal tin slime. Under the Government restrictions, no further machines could be made during the war, and hence it has been impossible to put them at work on the Cornish waste tin slime.

It is claimed by the company that their "Planetary" machine will enable the concentrating mills to recover more than two-thirds of the high percentage of tin which now runs to waste. Obviously, this would mean a vast increase in Cornwall's tin output.

Hitherto, tin slime had presented to the metallurgist an insoluble problem. The fine metallic particles cannot be separated out by any other of the existing concentrating devices. The company claims to have discovered that the reason for this comparative failure in tin metallurgy is the mechanical hold of the colloid on the metallic particles; these minute fragments are entangled in the colloidal constituents of the slime so firmly that the ordinary methods of gravity concentration, depending simply on differences in specific gravity, do not suffice to disengage them. The company's application of centrifugal force multiplies hundreds of times these differences and they become so wide that the metallic particles tear themselves free from the colloids and pack themselves on the wall of the bucket with the solid or crystalline contents of the pulp, constituting with them a clean product highly amenable to concentration.

Silver and copper slime also present a somewhat similar problem which the same machine should solve.

The machine was first designed for the clean separation of the cyanide solution from gold slime and sand, and for this work it was a success, but there is little doubt that its strong point in metallurgy is likely to be the recovery of the otherwise irrecoverable tin.

The company has had the intention of introducing the machine also in the work of purification of town sewage, separating the clear liquid from the solid matter.

For this work, however, the machine illustrated in Figs. 4 to 7 is probably the more suitable one. It is also continuous running, although the feed and discharge are intermittent; it never requires to be stopped for either feed or discharge. This machine has been manufactured in Johannesburg; it is of simple construction, and requires no high-grade steel, having no gearing. Machines of this type are running on the property of the South African Alkali, Limited, at Hamans Kraal, Transvaal, separating soda crystals from the mother liquor, and orders have been received for a further number. No doubt much of the South African business will be retained by the manufacturers, Messrs. Wright, Boag and Co., Limited, Johannesburg, but the Separator Company is endeavouring to open up negotiations with British and American firms for the manufacture of these machines on a large scale for the world's markets.

The machine is designed with either a simple-filtration drum (type No. 2A, the one shown in our illustrations, Figs 4 to 7) or with a decantation-filtration drum (type No. 2B, not illustrated). The machine type No. 2A effects straight filtration in the separation of soda crystals from the mother liquor. The separation drum is 2 ft. in diameter and runs at a speed of 1,400 r.p.m., delivering about five tons of soda crystals per 24 hours.

A machine now under construction has the same sized drum, and is designed for fully 2,000 r.p.m. Machines of this type are also intended for use in the continuous separation of the sugar crystals from the molasses. The type appears to be well adapted to the separation of alkalis, lending itself most conveniently to those operations of "fractional crystallisation" in which the various salts in a solution crystallise out separately at different temperatures, such as a solution of common salt and carbonate of soda, or those solutions which are complicated by the presence of, perhaps, gypsum at the one end and the more soluble potassium or soda salts at the other. It will come in for the continuous separation of liquids from solids wherever filter-presses are used.

The machine contains a perforated separation-basket, or drum, which revolves horizontally round a vertical spindle; the drum consists of two hollow cones, F and G, fitted together at their bases. The pulp is fed into it and the fluid is discharged through the filter screening of perforated walls into an external launder (Fig. 5). When the fluid has escaped, the drum is lowered by about 3 in. to bring it level with a lower receptacle; the drum then opens by the parting of its two halves, as shown in Fig. 7, and the solid material is instantaneously expelled into the second receptacle. The action is then reversed, the drum closing up and being raised into its original position, ready to receive a fresh charge. Figs 6 and 7 show the device by which the lowering of the bottom half of the drum is effected; it works most satisfactorily and smoothly.

The type of machine No. 2 B, alluded to above, and which is not illustrated, is said to be very similar to the one No. 2A, and likely to become the most striking of the company's inventions. Several machines of this type are in course of construction. It is specially adapted, in the manufacture of cane sugar, to the rapid purification of the mill juice. In other existing devices this juice has to pass through a number of appliances, clarifiers, eliminators, filter-presses, &c., before it is in a clear condition, fit for the vacuum evaporators, and the processes are slow and expensive; some are designed for separating the heavy earthy and vegetable matters, some for the light waxes and so forth, whose specific gravity scarcely differs from that of the syrup itself.

The company's machine, on the other hand, will carry out these processes at a single stage. It will attain in a few moments, partly by filtration and partly by decantation, the results of processes which are now protracted over days. The importance of this speeding-

CONTINUOUS CENTRIFUGAL SEPARATION MACHINES.

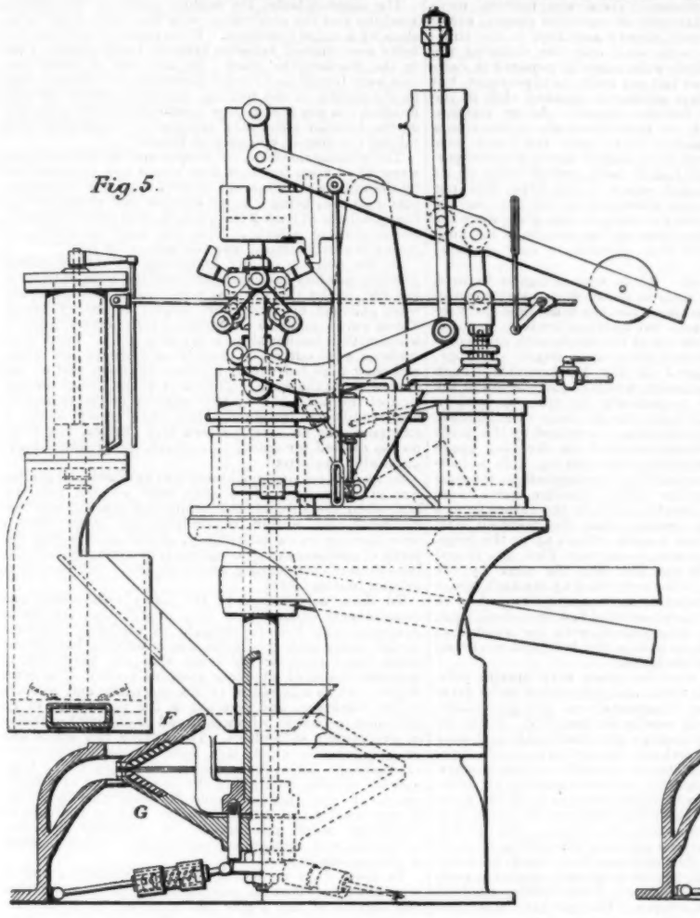


Fig. 5.

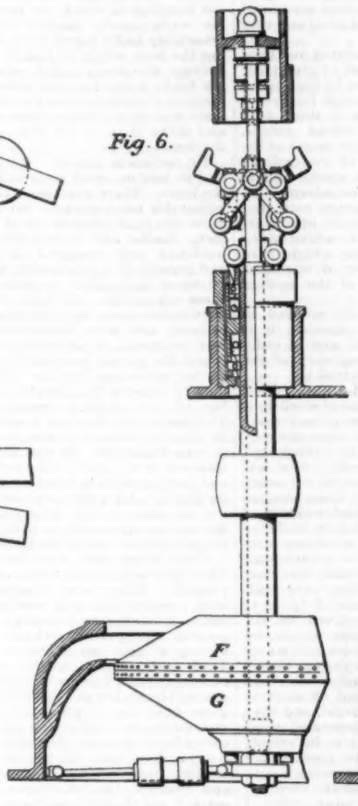


Fig. 6.

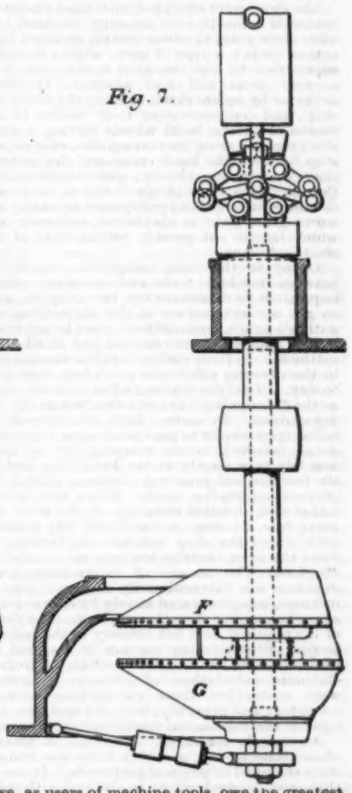


Fig. 7.

up in the treatment lies in the fact that the juice is extremely liable to destructive fermentation; even in the most modern plants, whilst the juice is being limed and sulphured, it starts fermenting on its slow way from the crushers to the quadruple-effect evaporators. The ferments or yeasts multiply with great rapidity and give rise to masses of slimy matter which are virtually insusceptible to any treatment. The company's machine brings about a rapid and uninterrupted flow of the juice to the vacuum pans; it thus saves time, prevents all danger of fermentation and avoids loss of sugar. There is a very urgent demand in all sugar-milling countries for a machine of this kind. Sugar being now manufactured at the rate of over 20,000,000 tons a year, if the claims made for the company's machine are substantiated, this should result in a material increase in the output of one of the most necessary of foods. In this connection Mr. Way remarked that there was no doubt that the machine had proved itself successful in separating certain products, thus carrying out work which could not be properly and economically done by any other means. The company had always had in view the enormous possibilities of the machine in the sugar industry. In dealing with inventions of this class, it was absolutely necessary to be in a position to demonstrate the actual working of a machine to intending purchasers. Owing to the war the arrangements to manufacture the machines in Great Britain could not be carried out, and the recent most satisfactory results obtained—a most important fact—had been with machines built entirely by a local firm of engineers.

As an engineer, he had followed the inventions connected with these problems with the very greatest interest for many years. He was confident that the company would be able to place upon the market continuous centrifugal separators of various kinds, which would be a commercial success and would revolutionise many industries which, to-day, almost entirely relied upon centrifugal separation for the manufacture of their finished products.

Separating machines have to centre themselves, they have to get over the critical speed, they are carried on ball bearings and the stage below the critical speed is hard on the bearings. Other types of machines of this class as hitherto manufactured, which have to be stopped for each discharge, wear out rapidly; besides this drawback, which is non-existent in continuous running machines, more duty for a given power can be obtained from continuous running separators of the type briefly described above.

MACHINE TOOLS.*

By Sir ALFRED HERBERT, K.B.E.]

WHEN the author was honoured by an invitation from this Institution to read a paper on machine tools, he was confronted by a difficulty in that the subject chosen is a very wide one. Any one of the large variety of machine tools in use, if dealt with in any detail, would afford matter for a paper of considerable length. It is obvious, therefore, that in the present paper the subject of machine tools must be approached very broadly and dealt with largely from a general point of view.

It has been said, with great truth, that man is distinguished from the lower animals, perhaps more completely than in any other respect, by the fact that he is a tool user, whereas they are compelled to rely exclusively on the limbs and organs with which Nature has provided them.

Man's complete domination over other forms of life on this planet, has been largely because—although very inadequately provided with natural means of asserting his superiority—he provided himself from the very beginning with weapons and tools of a constantly, though slowly, improving type. In these crude implements and weapons of bone, of flint and of bronze, we see the successive developments of the tool-creating and tool-using faculty. Probably in the potter's wheel is to be found the first germ of the machine tool itself. From producing by the aid of a rotating spindle cylindrical forms in plastic material, it is no great step to the invention of the first crude woodworking lathe, but the modern machine tool is a product of comparatively recent times, and its development coincides very closely with that of the steam engine.

It is known that the production of the steam engine was rendered extremely difficult by the lack of means for machining with sufficient accuracy its various components, and it was either Boulton or Watt who, in a letter written during the development of the steam engine, referred to the satisfaction and pride which was felt in having been able to produce a cylinder and piston of such accuracy that it was not possible to insert a half-crown between their respective surfaces, even at the worst place.

To Maudslay on the one hand, and to Whitworth on the other, we, as users of machine tools, owe the greatest debt. Maudslay is credited with the production of the first slide rest, and it was Whitworth who, by his accurate plane surfaces, and by his wonderful progress in exact measurements, became the father of mechanical accuracy. Given the ability to produce reasonably accurate cylindrical and plane surfaces, and given the slide rest, the evolution of machine tools became simply a question of time.

The lathe undoubtedly was the first real machine tool. It is of all machine tools even to-day the most important and the most universal, and in fact a lathe with appropriate attachments is capable of performing, after a fashion, most of the machine shop operations. The shaping machine, or "iron arm" as it was originally called, was also very early in the field, and from these two primitive types all the modern highly specialised machine tools have gradually been evolved.

In direct line of descent from the lathe, we find the milling machine, the boring machine, the drilling machine, the screwing machine, the capstan lathe, the automatic screw machine, the automatic turning machine, the universal and plain grinding machine and the boring and turning mill. From the shaping machine are descended the slotting machine, the planing machine and the surface grinding machine. Each of these various machine tools has been taken in hand by innumerable designers and developed into specialised types to meet the constant growth of demand—until to-day the machine tool family is enormous, both in range and in variety.

During the author's working life, machine tools and machine shop practice have undergone a great and most interesting development. In order the better to appreciate the extent of the changes that have taken place, the author proposes to give some brief notes of machine tools and workshop methods in use in the shop in which his apprenticeship was served :—

It was a shop employing some 200 men engaged in the production of a very varied class of work, comprising: hoisting and lifting machinery, stationary, portable and locomotive cranes, overhead travelling cranes, mill engines of a relatively advanced type, besides a large amount of general work. Judged by the standards of the day, the product was distinctly high-class, and the apprentices and workmen alike felt no small enthusiasm in the excellence of the work turned out. But the conditions obtaining, the methods in use, and the material available were crude and primitive when compared with modern practice.

The shops were large and lofty, and, while ventilation

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, on Tuesday, March 11, 1919.

left little to be desired, heating appliances of any effective character did not exist. There was, it is true, an arrangement by which, in periods of unusual severity of weather, exhaust steam could be introduced into the large columns supporting the roof and galleries of the shop, and after the stoker had consented to turn on the steam, it was possible to detect that the columns were, to some extent, warmer than the surrounding atmosphere. The result was, as might have been expected, that in the winter, and particularly in the dark and bitter mornings, everyone in the shop, except the blacksmiths, was more concerned in endeavouring to keep warm than in producing any very valuable output.

The shops were equipped with hand-operated overhead cranes of some 10 tons capacity, destined to give place after some years to power cranes, operated by high-speed cotton cords; a type of crane which, though long since superseded by the electrical crane, was in those days a very great and real advance. Overhead cranes, actuated by square shafts running the whole length of the shop, and communicating their motion to the crab by means of sliding bevel wheels driving a second square shaft running along the crane girder, were an intermediate step between the hand crane and the cotton cord, but they were noisy, clumsy, and complex in operation. Cranes driven by high-speed cotton cord carried along the shops on large idler pulleys and actuating a high-speed worm gear, gave a simpleness and ease of operation which lagged not greatly behind that of the modern electrical crane.

Owing to the close connection already referred to between machine tools and workshop practice, it is impossible to dissociate the two subjects, and in order to get a rough picture of the engineering shop of the author's youth, both subjects must be referred to.

It is appropriate to consider first of all drawing office methods. In those earlier days the amount of work done in the drawing office was much less than is customary to-day. Now, the drawing office is looked upon not only as the "designing" department, but as the "thinking" department. In earlier days, the drawing office was called upon simply to produce designs; but the necessary detail involved in the carrying out of those designs was left very largely to the knowledge and memory of the foreman and principal workmen, guided by tradition of previous similar work. When new machines were introduced, detailed drawings of the most troublesome parts were, it is true, prepared, but very usually machines with which the shop had become familiar were built from the most sketchy tracings on a scale of 1½ in. to the foot. The amount of information given on the drawings was extraordinarily meagre; gear wheels, for instance, being indicated merely by red circles with a note as to the number of teeth and pitch. The various classes of fits required were left entirely to the judgment of the works. Blue printing was not in use, and all working drawings were hand-traced on cloth. Careful, and even elaborate calculations of stresses in structural work were made, but these calculations were invariably corrected, and generally, let it be said, for good, in the light of the mechanical instinct of the proprietor.

As regards materials, there was a much narrower choice than to-day, and very little was known either of their chemical or physical properties. It was a tradition that steel, as steel, might be stressed with safety to such and such an extent per square inch, and that cast-iron, as such, might equally be regarded as safe with a compressive load of so much. Iron castings were obtained from outside sources. Foundry methods were extremely crude, analysis in its practical application to the foundry being unknown, and the percentage of scrap was considerable. Not only did castings suffer from blowholes, which were looked upon as inevitable, but local hardness, varying in degree from that which the tools could face with difficulty, up to that which they refused to face at all, was frequent.

Malleable castings of extremely poor quality and very badly annealed were used to some extent; steel castings in exceptional cases only. They were distinguished, in the author's recollection, mainly by the much larger amount of porosity that was found in them than in any other material, and also by the extraordinary difficulty in machining.

Mild steel, mainly bessemer, of fair quality, was available, but wrought iron was very largely used. In many cases it was full of seams, which had a dreadful effect on cutting tools, but which in other respects were not considered to detract from its value. Stampings, in the author's experience, were unknown. Of crucible steel there were two varieties; ordinary tool steel and "mushet" the latter being employed, with no small measure of success, on jobs which were too hard for ordinary tool steels.

The only means available for hardening and tempering tools was the blacksmiths' hearth. The whole subject of heat treatment, and the accurate determination of temperatures, was entirely unknown; and the only guide in tempering was by the colour, the tradition being that a turning tool should be straw colour, a drill the colour of a partridge's breast and that a chisel should be blue.

The large bulk of the machine-tool equipment was concentrated on, or under, a gallery, the heavy machines on the ground floor and some of the lighter tools on the gallery itself. The main line shaft was carried under the gallery, and was driven direct by a vertical engine, the crankshaft of which was, in fact, coupled to the line shaft. The larger machines were grouped outside the gallery, so as to be served by the overhead crane.

There was a good selection of heavy lathes, a large faceplate lathe and the usual equipment of planing machines, shaping machines and drilling machines. The author remembers that the largest planing machine, owing to an unfortunate accident in erection, had a broken bed. This had never been replaced, but was repaired by wrought iron straps, in which condition it continued throughout the whole of its working life.

Of measuring appliances, there was nothing more refined than a standard set of cast-iron gauges, which were treated with great respect and kept in the timekeeper's office, and were used only for checking the workshop gauges, which were made as required in cast-iron. The micrometer had not made its appearance, but workmen in those days possessed uncanny skill in the use of inside and outside calipers. As an instance the bearings in which the principal shafts of the cranes ran were usually bushed with brass, the holes were invariably badly bored, but a skilled turner after calipering the hole which he had to bush, and deciding on its average diameter, would return to his lathe, bore out his bush, make his own allowance in the bore for the amount of closing which was likely to take place when the bush was driven home, turn up the outside of his bush and drive it in to its final position, in most cases at the first attempt.

No tool-room existed. There were no jigs or fixtures, and in fact no small tools in the modern acceptation of the term. There were, it is true, the usual taps and non-adjustable hand reamers, but all the other tools required were the joint production of the blacksmith and workmen. Lathe and planer tools were forged to shape, hardened and tempered in the blacksmith's trough and ground on a grindstone, which it was the job of the youngest apprentice periodically to true up with a three-square file. All holes, except those of small size, were bored in the lathe to sizes determined by the inside calipers, and were finally checked by the plug gauge and corrected, if necessary, by scraping with a half-round file ground to a cutting edge applied to the hole whilst revolving in the lathe. Smaller holes were usually finished by a rosebit made by the turner from a bar of steel slightly smaller than the required size. The end of this bar was heated and set up at the forge. It was then turned to size, teeth were filed into it and it was hardened. It was fed into the work by the tailstock of the lathe, being supported by the back centre and prevented from rotating by a carrier clamped on to its shank. After the first few holes had been dealt with, the clearance usually disappeared, with the result that the rosebit frequently seized in the hole and wrenched the job entirely out of the lathe.

Twist drills were used for some very special jobs. They were kept in the office, and only issued under great pressure. They were sharpened on the grindstone, with a result that may readily be imagined. Drills for ordinary work were forged by the blacksmith, and were ground up by the workmen using them, each fitter having a large accumulation of drills in his drawer. There were no drill chucks, and consequently all drills, however small, had to be forged from steel of the same size as the socket of the drilling machine, in which they were held by a projecting set screw. The author remembers no more trying job than the drilling of small cotter holes in pins. The drill was first forged, probably from a ⅜-in. bar. It was then ground approximately to size, inserted into the socket of the drilling machine and clamped by the set-pin. The machine was then rotated and the drill was hammered until it ran approximately true. The table of the drilling machine being non-adjustable, it was necessary to build up with packing of various kinds until the necessary height was reached.

The packings available usually consisted of old collars, clutches or gear wheels surmounted by a "V" block. The drill was lubricated by a particularly evil-smelling oil which was kept in an old slide valve and was fed on to the drill by a tin spoon. As the whole of the packings became coated with oil, and as the drill usually ran out to a considerable extent, the whole structure of packing frequently collapsed during the process of drilling, resulting in a broken drill and a fresh start. The period during which the drill point was emerging from the underside of the job, was one of great anxiety, as the amount of drop in the spindle was usually not less than ⅛ in., and broken drills at this stage of the proceedings were again very frequent.

The author remembers particularly two drilling machines side by side on the gallery, which were provided for the use of the fitters. One of these machines had the hand feed wheel on the top of the spindle, and the bevel gears in the middle. In the other machine these positions were relatively reversed, and as no gear guards were provided either on this machine or any other, it can be imagined that the danger in changing from one machine to another was a very real one.

There was no cutting-off machine, no centring machine, no lathe centre grinder. All screws on turned work were cut by the screw-cutting tool and finished with a smooth file. Bars were cut off by the blacksmith to the approximate length required. They were centred with a centre punch and a lump of chalk. In cases of extreme refinement the apex of the centre hole was relieved by a small drill, which was rotated by a leather thong rapped round a bobbin on the shank of the drill, the drill being held up to its work by an iron plate resting on the lower chest of the operator.

The author remembers no lathe which could be relied upon to turn out parallel work without constant watching and calipering, but in time one got to know the general tendency of the lathe on which one was working, and knocked the tool into the work or away from it as the job proceeded. The tools were cooled by water cans, a chip of wood being inserted into the spout so as to direct the drops of water on to the point required. There were no sud trays attached to the machines, and the shop floor acted as the absorber of surplus water. As it was mainly composed of earth and cast-iron borings it was quite efficient in that capacity. Hardened mandrels did not exist. A large stock of battered soft mandrels were to be found under the lathes, but if a true job was desired it was usually necessary to turn up a mandrel specially before starting.

The capstan lathe, the milling machine, the grinding machine and the gear cutter were not represented in the shop by a single specimen. Even small motion pins and bolts were turned between centres, from forgings made in the blacksmiths' shop. In the case of small pins, two were forged and turned together with the two heads in the middle of the forging, and were parted off when finished; a pin that is now produced on the automatic or the capstan lathe in 2 minutes or 3 minutes, often taking the turner a couple of hours.

The planing machine, the shaper and the file and chisel were relied upon for work that would now be dealt with by the milling machine, the nearest approach to a milling cutter in use, being a small circular saw mounted on a flimsy arbour at least 3 ft. in length, and carried between the centres of a lathe. This was used for sawing up pieces of steel clamped into the lathe slide rest.

In the absence of any knowledge of the cylindrical grinding machine, all shafts and spindles were finished by the file, whilst the job was revolving in the lathe, and were polished by what were known as emery clamps. These were similar to exaggerated nutcrackers, made of wood with a leather strap to act as a joint. Their inner surfaces were cut away roughly to embrace the shaft, and they were fed with a mixture of emery and oil and moved along the work. The effect of the liberal lubrication of the lathe bed by this mixture of emery and oil can readily be imagined. The only emery wheel in existence was an early pattern tool grinder, but as no means existed for truing this wheel, the grindstone was invariably preferred.

As no gear-cutting machinery was available, all gearing was of necessity cast, usually from wooden patterns, and when the subject of machine-cut gearing was first discussed, the author remembers that grave doubts were thrown on its desirability, on the ground that the teeth of machine-cut gearing must, of necessity, lack the hard skin of cast gearing, and were likely therefore to be inferior in durability.

To those accustomed to the many refinements and conveniences of to-day, it may appear that the lot of workmen who had to struggle to produce creditable results under such conditions was a sad one, but, on the other hand there is no doubt that the very lack of appliances and of adequate machine tools did, in some degree, act as a stimulus to the ingenuity and resource of the workmen, and resulted in the production of an all-round mechanic, who was proud to display his ability in overcoming difficulties. The author can quote one or two jobs in which this fight against obstacles is exemplified. Take, for instance, the boring of the large number of holes required in the two housings of a steam crane. To-day this job would be dealt with by a boring machine of ample capacity, and in the case of repetition work jigs would be provided, locating accurately and without any setting the relative position of the various holes.

In those days no boring jigs were available, and in view of the fact that the gearing was of cast-iron and that the centres of the shafts had therefore to be accommodated to the varying sizes of the gears, no jig boring was possible. What actually happened was this: The gearing duly bored was laid on a rough plate, or even on the shop floor, and was put in mesh. Into the bore of each gear a strip of wood was driven, and on this strip of wood was marked the centre of the gear ascertained by the trammel. The distances apart of the centres of the train of gearing was then ascertained by trammelling from one centre to the other, and these centres were transferred to corresponding centres in strips of wood driven into the unbored holes of the housing.

From these centres circles were scribed on the bosses representing the sizes of the finished holes, and the boring was done to these scribed circles. It was a matter of some surprise to find, in spite of all these difficulties, that the gearing usually came together and worked in a fairly satisfactory way. As no boring machine was available of sufficient size to deal with these housings, the holes had to be bored by bars carried in wrought-iron straps which were bolted to the sides of the housings, the bars being rotated either by a handle turned by a labourer, or driven by belting from a convenient pulley on the line shaft. The bar was fed forward by a screw and differential wheels at one end, and was held up to the feed gear by a labourer, at the outer end of the bar, armed with a small breastplate and projecting centre which engaged with a centre hole in the end of the bar.

Another instance that the author remembers, showing what could be done in the absence of proper tackle, was the boring and turning of heavy engine flywheels of some 20 ft. in diameter. These were made in sections, fitted together by rough planing, and by the liberal use of the chisel and file. The wheel was then laid horizontally on packings over a pit, and the boss was bored by a vertical boring bar running in bearings attached to cross timbers fixed in the pit. It can be imagined that a great deal of care was necessary to ensure that the wheel should run sufficiently truly to be turned up, but, as a matter of fact, very little trouble was experienced in this direction. After being bored the wheel was keyed in position on the engine crankshaft; the shaft was then mounted in position in its proper bearings; an old lathe bed was bolted to the floor and fitted with a hand-operated slide rest; the wheel was then rotated by a rough cast-iron plate pinion which engaged with the barring holes cast in the periphery of the wheel, the pinion being driven through worm gearing from the line shaft, or, on occasion from a small steam engine. A chalk mark was made on the wheel, and the turner put on his cut and his feed by hand whenever the chalk mark came round. Tedious and crude as the methods were, the result in most cases was excellent, and the truth of the finished wheel was

quite equal, if not, in fact, superior to that which is attained to-day, though at an appalling cost in time.

Doubtless, there are many present who themselves are familiar with the difficult workshop conditions of thirty years ago, and who have watched the great advances that have taken place, but among the younger engineers present it is possible that these recollections of the old days may be of some interest, as showing what has been done for them by their predecessors, and as suggesting to them what they, in turn, have to do in order that they may hand over to their successors the benefits of similar improvements, and of even greater progress.

It is well that we should acknowledge our indebtedness to the United States for much of our progress in machine-tool production and in workshop methods. American tool builders were stimulated to a great extent by the high level of wages. When labour is expensive, employers cannot afford to waste it. The most efficient methods must be employed and manufactured goods can only be produced at reasonable prices when made in large quantities, and capital must be spent generously in equipping workshops in the most complete and efficient manner.

In this country wages for many years were at a comparatively low level, and British employers therefore did not have brought home to them the necessity of employing labour-saving machinery in anything like so forcible a manner as was the case in America.

There are those who would wish to close British markets to imported machine tools, but no more foolish proposal could be made. The introduction of American machine tools, developed under the special conditions obtaining in that country—mass production of output and dear labour—has, in the author's opinion, been of the greatest service to this country in preparing it gradually to meet similar conditions. Machine tools of the highest excellence are prime necessities to the whole of the engineering and allied trades of this country, and any policy which would tend to make it difficult or unduly costly for British machine tool users to obtain the best machine tools wherever produced, would be as short-sighted as the taxation of raw material.

Although it may appear paradoxical the author believes that taxation on imported machine tools would be a grave disadvantage to the British machine-tool maker, as well as to the user. Competition is the best stimulus in the world—it is nature's stimulus—and under it the British machine-tool industry has increased enormously in output and advanced correspondingly both in design and in excellence of workmanship. A policy of taxation on imported machine tools might temporarily please those British makers who are either inefficient or who wish to rest on their laurels without constant and renewed effort, but in the long run it would result in a serious check to progress, both in engineering generally, and in machine tool manufacture in particular. It must be remembered, too, that the immediate effect of protective tariffs is to increase cost of production, and this handicaps the British tool maker and the British tool user alike in the neutral markets of the world.

Repetition work was first seriously developed in the manufacture of small arms and of sewing machines. As soon as the possibilities of repetition work were realised, an immediate impulse was given to the improvement of machine tools and of measuring appliances and jigs and fixtures. Not only was it necessary to have machines and appliances of greater accuracy in order that the standard of interchangeability might be maintained, but the large number of pieces of a kind now required led to machine tools being produced specially designed to perform in a really efficient manner certain limited operations.

The manufacture of small arms, or of similar articles, required in very great quantities and without any changes in design, permits the system of interchangeable reproduction to reach its highest development. In the best practice each operation is performed on a machine specially set up for that operation, and used for no other purpose, this leading of course to great simplicity as regards each individual operation, but making on the other hand the greatest demands on the skill of the tool designer, toolmaker and gauge maker, and of the inspecting staff.

In the United States, Brown and Sharpe and Pratt and Witney were early in the field in the production of refined and specialised machine tools for manufacturing purposes. In the case of the former firm, the author believes that its first enterprise was the manufacture of the Wilcox and Gibbs' sewing machines; and as machinery, suitable for the very exacting requirements of high-grade sewing machine manufacture did not exist, the firm was led to design and build machine tools to meet the requirements of its own manufacturing department. It was soon realised that many other manufacturers were waiting for just such machine tools, with the result that machine-tool production very quickly became by far the most important part of the Brown and Sharpe business.

In England the early importation of these and similar American machine tools soon demonstrated that there was a market here for machinery of this class, and their gradual introduction among the more refined industries, had a valuable educative effect both on machine tool users and on the English machine tool trade. In this country the bicycle trade did more than is commonly realised for the advancement of workshop practice and of workshop equipment. Here was an article which rapidly came into great demand and the further demand for which seemed limited only by the extent to which its selling price could be reduced by successive improvements in methods of manufacture. The idea of repetition production and of interchangeability, made great progress in the bicycle factory, and the use of jigs and fixtures and of accurate measurements became familiar to a large section of the mechanical world.

It is a matter for some satisfaction that in the manufacture of bicycles British makers were for a long time in advance of America, and all the best bicycles in use in America were imported from England, even in spite of the heavy tariff then existing. This, of course, was mainly because this country set the fashion in design; and each season brought out new ideas which rendered last year's obsolete. So long as the lead in "fashion" was kept, so long was a profitable export trade to America possible, but when ultimately the bicycle became standardised and lost its seasonal character, the American makers soon supplied their own market.

The motor car industry afforded another great incentive to machine tool designers and makers, calling as it did for machinery of larger capacity than the bicycle trade, and also capable of dealing economically with the various new steels which the demands of the motor-car designer for strength and lightness had brought into existence.

The discovery of high-speed tool steel marked an epoch in machine tool design. It was indeed startling to find one's whole basis of thought completely upset. For years the limiting factor in the metal moving capacity of machine tools had been the endurance of the carbon steel cutting tool, which failed by softening and losing its cutting edge whenever heated by the friction of the cut sufficiently to draw its temper. The new self-hardening steels at once changed the limiting factor to the machine tool itself, for it became evident very soon that existing machine tools did not possess either the power or rigidity necessary to get from the new steels the results that they were capable of giving.

The immediate result was the scrapping of machine-tool patterns throughout the country, and the production of new designs embodying much greater weight and stiffness, accompanied with enormously increased power. A further development was a radical change in headstock design. It was soon evident that existing designs of lathe headstock failed to give the power required at the high speeds necessary to utilise the cutting capabilities of high-speed steel.

Here the all-geared headstock was introduced to give not only much greater torque at high speeds, but also to give a larger range of speeds, each speed capable of being brought into operation quickly and conveniently, and without the troublesome process of changing the driving belt from step to step of a cone pulley. The all-geared headstock again soon demonstrated that much better gearing was needed; that the gearing must be more carefully cut if it were to run at the high speeds required without giving trouble or creating unbearable noise; that it must in most cases be made of better material than cast iron; and, finally, that better provision must be made for its lubrication than the occasional drop of oil administered when the operator happened to remember its desirability. Thus we get the completely-covered gearing, running in an oil bath, making for quietness, durability and safety to the workman.

The same ideas of power, convenience, safety and quick-changing facilities spread very rapidly through the whole range of machine tool design, and were applied not only to main drives but to the feed motions. Comparatively recently the attention of designers has been directed towards relieving the operator of a good deal of the laborious work involved in moving saddles and other elements of machine tools; and in moden machines power operated adjustments are becoming standard practice on all the heavier types. It has been seen that the limiting factor in metal cutting was first the endurance of the cutting tool, and that by the introduction of high-speed steel the limiting factor became the driving power of the machine tools themselves. Then the all-geared head and other progress in design again shifted the limiting factor, which in many cases became the ability of the job itself to stand up to the cuts rendered possible by high-speed steel, plus ample driving power. This led to the introduction of roller steadies and other devices designed to support the work close up to the cutting tool, and much further progress in output was again rendered possible, by the greater rigidity of work and of tool, and by relieving the machine tool itself from many of the stresses causing deflection and vibration.

This paper would be incomplete without some reference to the effect on machine tool design and on workshop arrangement, rendered possible by the general introduction of electric power transmission. When first introduced, the failures and difficulties inseparable from any revolutionary innovation rendered the general adoption of electric driving slow and tedious; but the constant improvement in electrical producing and distributing plant, and in the electric motor itself, has caused an immense extension in electrical driving, and, in fact, it would be exceptional to find any engineering works of importance to-day in which electrical power distribution is not in use. There was a period in which the electrical enthusiast predicted individual driving for each separate machine, but the general trend of experience has been, so far at least as the smaller types of machines are concerned, towards group driving by electric power. Not only does this reduce very largely the number of motors required and consequently the capital and maintenance charges, but it also enables a group of small machinery to be run with a smaller total motor horse-power that would be the case if each individual machine was equipped with its own motor. On the larger machines, however, it is becoming more and more recognised that it is desirable for individual motors to be used; and in many cases motors are incorporated in the design of the machine, and this again has led to many modifications in order to adapt the machine more completely for electrical driving.

Among other advantages of the individual electrical drive in the case of large machines, is the facility offered for placing the machines in the most convenient situations irrespective of their distance from the power station, and also of so disposing them as to be served efficiently by cranes without the interference of belts and countershafts. In certain classes of machines, the tendency is to go beyond the mere driving electrically, and to introduce in addition electric controls. This is well exemplified in the latest designs of planers, and the author ventures to offer the opinion that the future will see further and large developments in this direction.

Interesting work has also been done in the direction of hydraulic control of the various motions of machine tools. So far, work in this direction has been largely experimental, but there has been at least one instance during the war, within the author's knowledge, in which on work of a purely repetition character, hydraulic control has been applied with very considerable success. Another interesting development of comparatively recent times has been the introduction of optical methods into the more refined classes of precision machinery in connection with the production of accurate screws and the reading of close measurements, and it would appear likely that further progress in this direction is to be expected.

The machine tool trade was affected to a very considerable extent by the war, but it was spared the complete dislocation which so many other branches of engineering suffered through the necessity of changing entirely the nature of their output. At the first declaration of war there was a curious lull in the demand for machine tools, and some time elapsed before there was any general recognition of the extent to which machine tools would be necessary. As the demand for shells became more and more insistent, and as every existing shell plant became occupied to its utmost capacity day and night, it began to be realised that further and still further increases in shell production could be effected only as additional machine tools became available.

Even before the Ministry of Munitions was brought into being, steps were taken by the Government to deal with a situation which was full of the gravest anxiety, and instructions were issued to the machine tool trade, the general effect of which was to make it clearly understood that all efforts must be concentrated on the output of machinery for war work, and that everything else must give way. When the Ministry of Munitions was established the question of machine tool supply received further attention, and all machine-tool works of any importance were made controlled establishments and, as such, were required among other things to submit their orders to the Ministry for approval, and not to increase their prices without permission. The first provision was necessary to ensure that no machine tools should be supplied except for the urgent war requirements of ourselves and our Allies, and the second to protect the purchaser in the temporary suspension of the laws of, supply and demand against undue and unreasonable charges.

British machine-tool makers were encouraged by the Ministry to increase their output of standard tools wherever these were suitable for war purposes. They were urged to establish night shifts wherever labour for this purpose could be obtained and to employ female labour on all work which women could perform successfully. For the purpose of increasing output and of avoiding the employment of any unnecessary labour the trade was asked to eliminate polish and to reduce painting to one single coat, and generally to omit all finish of a non-essential character, but it was always made clear that accuracy and high quality of workmanship must be maintained. It was obvious to the Ministry that the ever-increasing demand for machine tools could not be met by the established machine-tool makers alone, and it was necessary to call in the assistance of other branches of the engineering trade to assist, either by the production of machine tools to their own designs, or alternatively by undertaking work as sub-contractors to machine-tool builders.

A large amount of most valuable work was obtained in this way from many firms who abandoned their own regular trade in order temporarily to make machine tools, and in many instances with great success. Messrs. Turners, of Ipswich; the Hunslet Engine Company, of Leeds; Messrs. Blackstone, of Stamford; and the British United Shoe Machinery Company, Limited, of Leicester, being conspicuous examples.

During this time large quantities of machinery were being imported into the country from abroad, particularly from America, though some useful machinery was obtained from Switzerland, Scandinavia and from Spain. There were in evidence large numbers of optional snatchers drawn into the trade by the hopes of rapid fortune-making. It was the practice of these gentlemen to bid American manufacturers enormous prices in order to secure options on certain batches of essential machine tools, and then to offer the machines to the Government. The effect of this activity was to stimulate the already very rapid increase of American prices. It became necessary at an early date to prohibit the importation of machine tools except by licence, and to grant licences only to the *bona fide* established importer. The licence was issued subject to regulations limiting the percentage of profit permitted to the importer, forbidding him to sell his goods except to the actual and approved user and forbidding him also to compete in America by attempting to secure agencies held by his duly licensed competitors by offering higher prices.

Although it was possible by these measures to control and to keep at a reasonable level the margins of profit to the British importer, it was, of course, quite impossible to limit the prices charged to the importer by the American producer, and American prices rapidly reached a very unreasonable level. The British machine-tool merchant had also to be considered, and regulations were framed limiting the merchant's profit and forbidding the sale of machine tools by one merchant to another. Cases were brought to light in which machine tools had passed through the hands of five or six merchants before

reaching the unfortunate user, at a price bearing no relation to their value, but always bearing some proportion to the number of hands through which they had passed. But it was recognised very quickly that in spite of all that could be done by the British maker with the assistance of all sub-contracting help that could be obtained, and in spite of all that the licensed importers could accomplish, the supply of machine tools was still quite inadequate, and the Ministry were compelled to send a special mission to America to obtain further supplies direct.

It was found that all regular machine tool builders in the States were so congested with orders that it was hopeless to expect deliveries from them within any reasonable time, and consequently steps had to be taken to arrange for the manufacture of machine tools by American engineering firms who were not machine tool makers. In many cases machine were built to British designs largely supplied by Messrs. John Lang and Company, whose lathes had established a high reputation for projectile work.

Finally, from all the various sources the supplies began to overtake the demand, and a period was reached when no further anxiety was felt as to the provision of projectile machinery in sufficient quantities. But although the earliest and most urgent pressure was in respect of shell-making plant there was also a great and constantly-growing demand for other types of machine tools required for motor transport work, for aeroplane work, for the building of tanks, for gauge making, for optical work and for shipbuilding—to mention only a few of the principal requirements—and up to the signing of the Armistice machine-tool builders were still pressed up to the limit of their resources.

All this war activity has had its effect on machine-tool production and machine-tool producers and users. In all directions the manufacturing idea has been encouraged, and great attention has been concentrated on efforts to secure cheap and rapid production in spite of the many difficulties due to shortage of labour and to other causes. The need for much greater accuracy than was previously attained in connection with repetition and interchangeable work has been emphasised, and ingenuity has been stimulated to devise better and more accurate workshop methods. In the production of accurate screw gauges alone much valuable progress has been made which cannot fail to have a wide-reaching effect in engineering generally.

The introduction of new types of machine tools during the war has not been great and no very revolutionary inventions in this direction have come to the author's notice; attention having been directed mainly towards selecting those existing types of machines which best lent themselves to the work required and to producing and reproducing these types in ever-increasing quantities.

While the war atmosphere has been a stimulating one it has, of necessity, been an artificial one, inasmuch as the demand was such as to relieve machine-tool makers of any repute from all anxiety as to the obtaining of orders. There was an eager market even for machine tools of inferior grades, and in general terms the buyer sought the seller, and competition was greatly reduced. But with the cessation of hostilities and the cancellation of Government orders conditions are changing and true levels will in due course be attained. Great masses of engineering plant have been thrown idle at least temporarily, and a good deal of time must of necessity elapse before useful work is found for all the available producing capacity.

The best brains of the country are engaged in the great task of reconstruction of industry, but the task is no easy one. Manufacturing concerns which, for the past three years, have been pressed to the utmost to keep up with a constantly-increasing stream of Government orders, are compelled to bring their programmes to an end and to turn their energies to the satisfactory employment of their resources on work required for peaceful purposes. In many cases this involves new designs, new patterns, new tools—jigs and fixtures, new selling organisations and most difficult of all, new relations with labour. There is a world shortage of almost every commodity, and for a long time a market is assured to all engineers who can succeed in so effecting the necessary changes in their works and in their organisations as to obtain an early output of acceptable goods.

But the new conditions with which industry finds itself surrounded are perplexing to a degree. Nothing is stabilised and it is impossible to see far ahead. Prices of many commodities are at a level which obviously cannot indefinitely be maintained. Labour is filled with unrest and shows little inclination to settle down to steady productive work. Money has been raised for war purposes to such an extent and spent with such laviahness that a false impression has been created as to the ease with which money and credit can be obtained, and the fact is lost sight of that while money can be produced on the printing press for temporary and internal purposes, yet such money is useless for international trade. Abundance of paper money at home goes hand in hand with lack of national credit abroad, and the country can only be put on to a satisfactory financial basis by the gradual building up of its dissipated resources and impoverished credit, and this can be accomplished only by production on a scale far in excess of what has been attained before the war.

There is no question that the present labour unrest militates more than any other factor against our early resumption of satisfactory industrial conditions. Projects affording almost unlimited scope for the employment of labour are held up day after day because of an entire lack of confidence in the future, and it seems impossible for industry to settle down to a satisfactory basis and for full employment to be found for labour, capital and plant until the present constant irritation and uncertainty can be removed. There has never been a time in the history of industry when the employer was prepared to meet the difficulties of labour so frankly and wholeheartedly as at present, but when all is said and done it is an unchanging law that in the long run labour can be remunerated only out of the wealth created by the joint utilisation of capital and labour.

The idea which appears to be held in some quarters that somewhere or other is a vast reservoir of wealth which can be drawn on to any extent is at the root of many of the misunderstandings and troubles from which the country is suffering to-day. Large projects of extension to industry and of the establishment of new manufactures are held up indefinitely, and until mutual confidence is restored and earnest and uninterrupted work can be relied on, satisfactory progress cannot be made.

The kind of vicious circle towards which at the present time so many businesses tend to drift is well illustrated by the motor car industry. Here is a trade which has suffered enormously from the necessity of abandoning entirely its regular production of motor vehicles and of devoting itself for the last three years to Government work in nearly all cases of a special character. The sudden cessation of Government work makes it necessary for the industry to get back to peace-time production at the earliest moment, and practically every motor car company has decided on a programme of output, and is working towards the realisation of this programme, but the uncertainties as to the cost and attitude of labour and the similar uncertainties regarding values and supplies of raw materials, affected in their turn by the labour position, makes it almost impossible for definite prices to be fixed or for definite deliveries to be guaranteed. The country is eager for motor cars, but the purchasers are holding back largely because it is impossible to secure definite dates of delivery, and also because there is an entire lack of knowledge as to what the future values of motor cars are likely to be.

Similar conditions prevail in almost every industry and, while this country is drifting in many cases towards a policy of "wait and see," the United States is bending its immense energies and utilising the enormous wealth which it accumulated in the early stages of the war, towards the most energetic, industrial campaign in the history of the world; and unless Great Britain is enabled very rapidly to settle down it will find itself forestalled to a very large extent in the foreign markets of the world.

The large accumulation of machine tools in this country is a source of some anxiety to the machine-tool manufacturer, but the author has little doubt that given stabilised conditions the great bulk of this plant can be rapidly brought into satisfactory employment. Much of the existing plant has been put down with special reference to the provision of projectiles, and in the entire cessation of demand for this product such plant has only a limited utility and, moreover, owing to the conditions under which it has been worked, it has depreciated to such an extent as to be mainly useful only for rough and simple work. But on the other hand the plant that has been put down for more refined purposes, such as the manufacture of aero engines, is of a nature for which abundant employment will be found as soon as the country settles down, and the author has little fear but that the machine-tool trade of the country will find abundant occupation in supplementing and balancing existing plants and in meeting the demands of new manufacturing industries. Many of the less advanced engineering firms have learned from their experience in the war work that they have been compelled to undertake the necessity of more complete and better machine-tool equipment and, with the certainty of much more costly labour and of shorter working hours, the provision of really adequate machine-tool plant must be faced.

Some consideration may well be given to the general effect of the modern machine tool on labour.

Just as the advent of mechanical methods into the textile and similar trades gave rise to the wildest apprehension on the part of the hand-loom weaver that his livelihood would be taken from him, even so the introduction of labour-saving machine tools gave rise to similar misgivings in the minds of the old-time fitter. But although in both instances some immediate disturbance and need for adjustment to meet new conditions arose, yet it was soon made evident that so far from being reduced the actual effect was largely to increase both the demand for labour and the amount of its individual earnings.

Besides the large number of highly skilled workers required for the production of the machine tools themselves, the great development of engineering industry as a whole, due to improved tools and methods, created an ever-growing demand for labour, and this growing demand led inevitably to a steady increase in wages. Even before the war the earnings of a competent worker was in many cases at least twice as great as those of his predecessor of five and twenty years ago, and whatever the condition of trade it has been rare indeed for a really competent workman to suffer unemployment.

But there is another and a very important effect on labour brought about by the modern machine tool. A new class of labour has, in fact, been created. The tool maker, the jig maker, the inspector, the machine-tool charge hand, the machine-tool demonstrator, the process setter and the rate fixer have all, in fact, been brought into being by the modern machine tool in its application to mass production. This class of labour has been recruited from the more intelligent, the more earnest and the more thoughtful among the rank and file. It is a class that is highly paid, and enjoys many opportunities of improvement and promotion to other and still more important responsibilities.

The machine-tool maker is constantly confronted by instances in which expensive machine tools are bought and installed, and from which the user does not reap the full measure of benefit which the tools are capable of giving. To build a piano needs much skill and ability, but to play it with a master hand is an even more difficult undertaking. And so to get from a group of modern tools the output which they are capable of giving needs skill, determination and energy of no mean order. The future would seem to the author to be full of opportunity for the aristocracy of labour in so controlling the selection, the setting up and the running of modern tools, as to justify the capital expended in their purchase.

There is, of course, another direction in which all labour has reaped, though less obviously, great advantages from improved machine tools. Reference is made to their immense effect in cheapening production of essential commodities, and thus bringing within the reach of the worker comforts and conveniences which would otherwise have been unattainable.

INSTITUTE OF CHEMISTRY.

AT the forty-first annual general meeting of the Institute of Chemistry, held at 30, Russell-square, on Monday, the 3rd inst., Sir Herbert Jackson, the president, referred to the work of the Institute during the war. The record afforded an example of the value to the country of organised professional bodies in times of crisis. The report contained a concise statement indicating the various directions in which chemists had rendered good service both with the forces and in industries connected with the war.

The Institute was now co-operating with the Appointments Department of the Ministry of Labour in the resettlement in civil life of those who have been so engaged, and it was hoped that with the return of more normal conditions chemists would be utilised to the fullest benefit in the application of their science to the industries of the country. The president, in referring to the losses sustained by the profession, mentioned especially Lieutenant-Colonel E. F. Harrison, who would always be remembered for his exceptional work in the provision of means of defence against poisonous gas attacks, to which work he undoubtedly sacrificed his life.

The Institute had before it a period of reconstruction, and would endeavour to bring together in one body the trained and competent chemists both for their own benefit and for that of the community. The regulations had been modified on such a broad basis that it was hoped all qualified chemists would be able to take part in promoting the welfare of their profession. The council hoped in the near future to arrange a conference to review the subject of the training for a chemist. Local sections were being formed in various parts of the country, and the method of the election of the council would be amended to ensure that its constitution was properly representative of all districts and all branches of professional work. Events of the war had done much to establish the claim of chemists to greater recognition than had been accorded them in the past. The council had recently prepared a scheme of Government chemical service which they hoped would secure better conditions for chemists holding appointments under various departments. The vital importance of chemical service to the State had been clearly demonstrated in recent years, and a good example set by the Government would go far to bring home to the public the importance of chemistry to industry and commerce.

THE INDUSTRIAL RECONSTRUCTION COUNCIL.—A meeting will be held in the Saddlers' Hall, Cheapside, E.C. 2, on Wednesday next, the 19th inst., The chair will be taken at 4.30 p.m. by the Right Hon. the Lord Mayor of London, Sir Horace Marshall, LL.D., and a lecture entitled "The Functions of Government in Relation to Education" will be delivered by the Right Hon. H. A. L. Fisher, M.P., President of the Board of Education. Applications for tickets should be made to the Secretary, I.R.C., 2 and 4, Tudor-street, E.C. 4.

CONTRACTS.—The Hydraulic Engineering Company, Limited, Chester, have secured the contract for the gate machinery required by the Mersey Docks and Harbour Board for operating the south and middle lock gates of the 90-ft. passage between the Gladstone and Hornby docks at Liverpool. The method of operating the gates will be on the "Norfolk" system, wherein each gate leaf is operated by means of a strut applied to the leaf about the centre of pressure, actuated by rope or chain connections to a hauling machine installed above water level. In this system each leaf is operated from the one side of the lock, so that chains crossing the lock, the paying out of slack chain and other disadvantages of the obsolete chain systems, are eliminated. A considerable economy, both in time and power, for working the gates is also effected.—The Dowson and Mason Gas Plant Company, Limited, Levenshulme, Manchester, have received an order for a 70-ft. "Weardale" angle-bar furnace by Messrs. Vickers, Limited, Barrow-in-Furness. Two similar furnaces were installed in 1910, and this is a repeat order. They have also just completed for the Blyth Shipbuilding and Dry Docks Company, Limited, a 63-ft. "Weardale" frame-heating furnace, and have in hand for Messrs. Swan, Hunter and Wigham Richardson, Limited, for their Sunderland yard, a 45-ft. frame furnace, and for their Wallsend yard a plate furnace, 26 ft. by 6 ft. wide. At the Middle Docks and Engineering Company, Limited, they have just completed a town's gas fired plate furnace, 40 ft. long by 10 ft. 3 in. wide. This is the largest town's gas fired furnace for plate heating work that has been installed in this country, and is giving very satisfactory results.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

ELECTRICAL APPARATUS.

121,490. J. S. Highfield, Kensington, London. Electric Generators and Motors. (3 *Figs.*) January 18, 1017.—This invention relates to dynamo electric machines intended to work submerged. According to this invention, a stator or rotor winding of the machine is contained in watertight slots or channels in the stator or rotor core and the end connections of the windings are covered by casings or covers to prevent water obtaining access to the winding. The motor comprises a casing 1 having internal projections 2 between which is arranged the stator core consisting of laminations 3. The laminations 3 are contained within a gun-metal sleeve 4, and are held between end plates 5, 6. The stator windings 7 are arranged in closed slots. The end connections 8 of the stator winding (shown diagrammatically

Fig. 1.

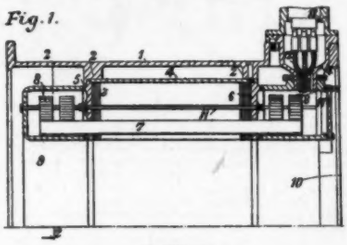
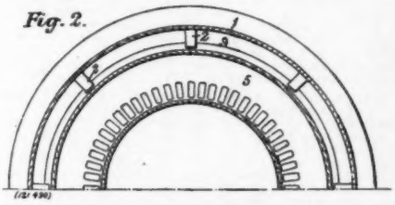


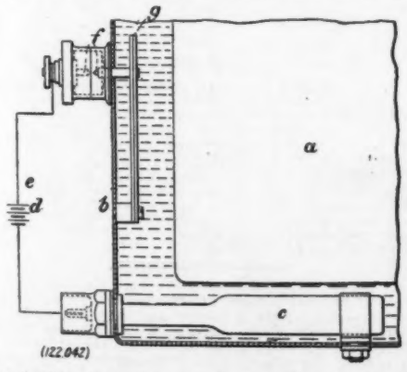
Fig. 2.



in Fig. 1, but not shown in Fig. 2) are encased by annular dish-shaped gun-metal covers 9, 10. The end plates 5, 6 are held together by bolts 11 extending through, but insulated from, the laminations 3. The bolts 11 also extend through the end covers 9, 10. Conductors 12 from a coupling 13 pass through a gland 14 opening into the cover 10. The cover 10 is also provided with an opening which can be closed by a cover plate 17. The conductors 7 in the stator slots are wrapped in layers of micanite, forming troughs and an outside covering of leatheroid is provided. After the conductors 12 are joined to the stator winding, insulating compound, which sets as a solid, is forced through the opening closed by the plate 17, so as to fill up the covers 9, 10, and all the spaces left in the stator slots and between the laminations. (*Accepted December* 31, 1918.)

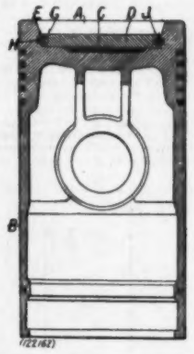
GAS ENGINES, PRODUCERS, AND HOLDERS, &c.

122,042. F. R. Simms, London, and Simms Motor Units, Limited, London. Internal-Combustion Engines. (1 *Fig.*) January 15, 1918.—The invention has reference to the water circulation with which internal-combustion engines are provided for cooling purposes. According to the invention, one or more electric heating devices are immersed in a suitable part of the water circulation, the supply of current to such



devices being controlled by a switch under the action of a thermostatic device, the arrangement being such that the circulating water can be heated as and when required. *a* indicates a part of the radiator of an internal-combustion engine and *b* the water jacket thereof. *c* is the electrical heating device which is immersed in the water in the jacket *b*, this device being supplied with current from a battery, represented at *d*, through a circuit *e* which includes the switch *f*. This switch is controlled by the thermostat *g* in such a manner that it is closed when the circulating water in the jacket *b* cools down to a predetermined temperature, and is opened when the temperature of the said water rises above the predetermined limit. The invention is particularly suitable in connection with aeroplane engines, where the stoppage of the engine frequently causes the machine to drop, and the rapid dropping motion through the air cools the circulation water to such an extent that the restarting of the motor is rendered difficult or impossible. As will be obvious by the invention the water is prevented from becoming cooled to too low a temperature, so that this difficulty is not met with. (*Accepted January* 22, 1919.)

122,162. North British Diesel Engine Works, Limited, Whiteinch, Glasgow, and J. C. MacC. MacLagan, Glasgow. Internal-Combustion Engines. (1 *Fig.*) October 28, 1918.—In certain types of pistons for internal-combustion engines it has hitherto been proposed to provide a protective metal plate in the head of such pistons so as to prevent or lessen the possibility of the crown thereof becoming overheated, and this invention has for its object to provide an improved piston of this type. A circular recess A is formed in the crown of the piston B, the mouth of the recess being flared as shown. In the bottom of this recess is a depression which is filled with asbestos C. Within the recess there is fitted a protective metal plate D. The plate D is retained in position by a split ring E similar to an ordinary split piston ring of the Ramsbottom type. A groove G in the plate D receives the ring E, this groove being of sufficient depth



laterally to entirely contain the ring E when the latter is compressed. The outside diameter of the ring when uncompressed is considerably greater than the diameter of the plate D. In the vertical wall of the recess A there is a groove H of a lateral depth approximately equal to half the lateral depth of the groove G. In order to insert the plate D and ring E in position in the recess in the piston top, the ring is compressed into the groove G until its outside diameter is equal to that of the plate. The whole is then pressed into the recess in the crown, until the grooves G and H coincide, when the compressed ring springs into the groove H, assuming the position shown in the drawing, and thus holding the plate D in position in the recess. A screw J is inserted behind the ring E when the latter is finally in position, to prevent it from becoming displaced. (*Accepted January* 22, 1919.)

122,072. J. L. Norton, Aston, Birmingham. Internal-Combustion Engines. (2 *Figs.*) March 5, 1918.—This invention relates to means for cooling internal-combustion engines. The engine cylinder is represented at *a*, and the crank-case at *b*; *c* is the crankshaft, *d* the driving sprocket or pulley, and *e* the valve turning gear cover. The engine cylinder, including the cooling fins, is enclosed in a casing or cowling *f*, which may be formed in two main portions, bolted, riveted or otherwise secured together through flanges *g*, Fig. 2, and with a closing cap or cover *h* screwed or bolted in place. This construction is not essential, but is a convenient one permitting easy fitting, and, owing to the removable cover or cap, ready access to the cylinder head and valve caps when desired. In this engine, which follows on well-known lines with the valve chamber at the side of the cylinder, the casing encloses the valve chamber with the cylinder,

Fig. 1.

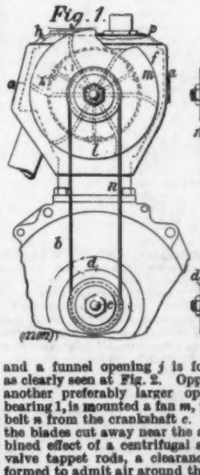
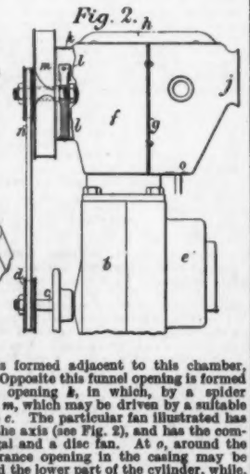


Fig. 2.



and a funnel opening *j* is formed adjacent to this chamber, as clearly seen at Fig. 2. Opposite this funnel opening is formed another preferably larger opening *k*, in which, by a spider bearing *l*, is mounted a fan *m*, which may be driven by a suitable belt *n* from the crankshaft *c*. The particular fan illustrated has the blades cut away near the axis (see Fig. 2), and has the combined effect of a centrifugal and a disc fan. At *o*, around the valve tappet rods, a clearance opening in the casing may be formed to admit air around the lower part of the cylinder, while, as shown at Fig. 1, air inlet openings *p* may be formed in the casing around the sparking plugs or plug. Similarly air inlet openings maybe formed at other convenient points in the casing, but the number and area of openings nearer to the fan than the main funnel opening *j* should be arranged so as to maintain an efficient stream of cooling air through that opening *j*. (*Accepted January* 22, 1919.)

MOTOR ROAD VEHICLES.

121,997. T. Clarkson, Galleywood, Chelmford. Motor Road Vehicles. (3 *Figs.*) December 27, 1917.—This invention relates to condensers or radiators for motor road vehicles, more especially those propelled by steam power. In a condenser or radiator of the type comprising parallel tubes arranged between two plates carried by or forming part of headers, it is customary to rigidly connect the headers to side members so that the latter and the headers form a fixed rectangle. When the tubes become heated, particularly when steam is passed into them for condensation, the expansion of these tubes tends to bring about distortion, or they become loosened in the tube plates unless mounted in these plates in such a manner as to provide for this expansion. The condenser comprises a series of parallel tubes A which are fixed at each end to two plates B and C. Each of these tube plates forms one wall of a horizontally-disposed header, the tubes running vertically between the headers. One of these headers D, which lies at the top of the condenser, is rigidly connected at its ends to two side-frame members E, each of which is of channel section, with a bracket E^1 on its outer side, by means of which it can be mounted on and attached to the side members F of the vehicle frame. Each end of the plate C, which

Fig 1

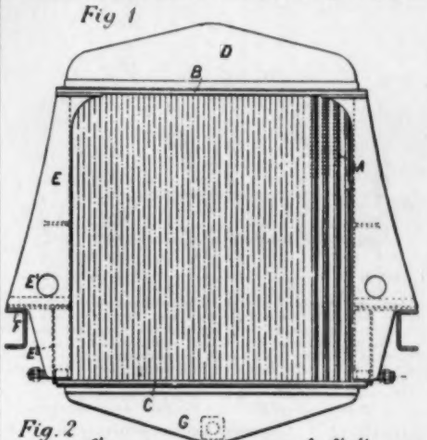


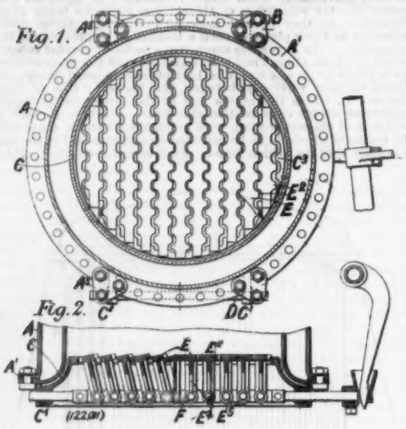
Fig. 2

is attached to the bottom header G, lies within the channel formed by a side member E, and is embraced by the flanges E^2 of this member. A block C^1, which projects on the upper side of each end of the tubeplate C, fits freely within this channel, so that it can move vertically as the tubes A expand. The bottom header G is thus suspended as it were from the top header D, by the tubes A, and when the latter expand the bottom header can move downwardly in the side members E. Each block C^1, at the end of the tubeplate C, carries two bolts or studs H which are directed laterally, and pass through slots or holes of larger diameter than the bolts formed in a diaphragm plate E^3, which extends downwards from the bracket E^1 and between the sides E^2 of the member E. Around the outer part of each of these bolts is a coiled spring, beyond which is a nut so that one end of the spring bears against the nut while the other end abuts against the outer face of the diaphragm plate E^3. The arrangement is such that the header G can move as described vertically in the side members E, being only constrained against undue movement between the flanges E^2 of the latter by the bolts H, which also, by means of the springs, prevent such movement as would tend to cause vibration and noise between the parts. (*Accepted January* 22, 1919.)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

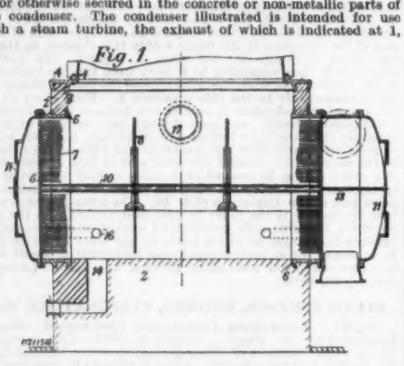
122,011. T. Clarkson, Galleywood, Chelmsford. Steam Generators. (6 *Figs.*) January 8, 1918.—This invention relates to the furnaces of steam generators of the vertical type. The casing A of the generator, which is circular in cross-section, is flanged outwardly at its base A^1, and to this casing is pivotally connected by a hinge A^2, B, a ring C of such shape and dimensions as will fit closely against the bottom flange A^1 of the generator casing, ring C, according to one construction, being there retained by a horizontal pin D, which passes through lugs C^1 and A^3, on the ring and casing respectively. When the pin D is withdrawn, the ring C can turn about its hinge B, and so lower the grate as to permit the fire to be drawn. Oppositely arranged on the inner periphery of the ring are a series of bearings C^2, each formed conveniently as an approximately semi-cylindrical groove. These grooves are adapted to receive the ends of the fire bars E, each of which is formed at its ends with a cylindrical part, the upper part of which is cut away so as to be a smooth flat continuation of the flat upper surface of the fire bar. Along each edge of each fire bar are formed a series of projections or serrations E^2. These projections may conveniently have squared ends, the spaces between each two projections being conveniently curved. The projections are so disposed on adjacent bars that they will alternate when the bars are in place in the ring C, that is to say, each projection E^2 on the edge of a bar will lie in the space between two projections on the opposite edge of the next adjacent bar. As the contour of each projection E^2 differs from the contour of each space between the projections, there will be formed an irregular air space between each two bars, the width or dimensions of which will be dependent on the shape and dimensions of the projections and of the spaces between them. Those bars E which lie across the centre portion of the ring have the spaces between their projections E^2 reduced at the centre portions of these bars as compared with the dimensions of those spaces at the ends of these bars. Thus the air spaces between each two bars will be less at the centre of the grate than towards its edge, as clearly shown in Fig. 1. Preferably this variation in the dimensions of the air spaces is such that the amount of air that can pass through the grate will be greatest around or towards the edge and least at and around the centre, the spaces conveniently being graduated between extremes to obtain this effect. The projections E^2, on the outer edges of the two outermost bars of the series intercalate with corresponding

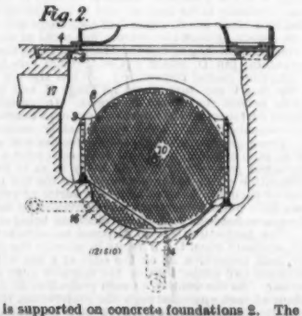
projections C^3 formed on or fixed to the grate ring. On its underside each bar E has a downwardly directed flange E^4, which constitutes an arm, and is deeper at the centre of the bar than at its ends, the bar in side elevation thus having a V-shape with a considerable angle between the edges which form the arms of the V. At this angle is formed a lug E^5, through which is a transverse hole. The lugs E^5 of all the fire bars lie in a space between two parallel bars or members F, which form part of a rod extending across a diameter of the grate ring C at right angles to the fire bars E. The fire bars lugs E^5 are all pivotally connected by pins which pass through holes



formed in these parallel rod members F. The rod F is carried at its ends in bearings formed by two lugs C^4 constructed on the underside of the grate ring C. Thus movement of this rod F in the axial direction will result in a rocking movement being imparted to all the fire bars E simultaneously. The effect of this rocking movement is to cause the projections E^3 along one edge of each bar to rise while those projections along the opposite edge of that bar fall so that a slight lift is given to the fuel resting on the bars and formation of clinker between the bars is prevented. This movement is indicated by the positions of the fire bars E on the left-hand side of Fig. 2. (*Accepted January* 22, 1919.)

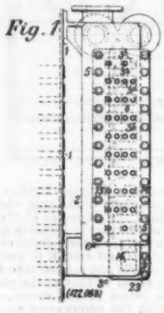
121,510. A. E. L. Scanes, Ashton-on-Mersey, and O. R. Verity, Hale. Surface Condensers. (6 *Figs.*) December 15, 1917.—This invention relates to surface condensers. According to the present invention, the shell or outer wall, and such other parts as may be desirable are formed of cementitious material, or clay material, which in some cases may be reinforced with metal, and the tube plates and water boxes are secured in or against openings in said shell or wall. The inlet and outlet pipes, the pumps, tubes, manhole covers, and other accessory parts, which it is necessary or preferable to form of metal, are attached by suitable joints, and if necessary to metallic seats embedded in or otherwise secured in the concrete or non-metallic parts of the condenser. The condenser illustrated is intended for use with a steam turbine, the exhaust of which is indicated at 1,

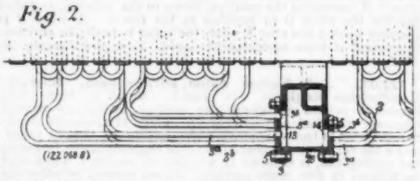




and which is supported on concrete foundations 2. The foundations are constructed with a large hollow space, which forms the shell of the condenser, the upper opening or steam inlet 3 being provided with a metallic piece 4 grouted into the concrete, which may form part of the bedplate for the turbine. The tube plates 5 at the end of the condenser shell are secured to metallic rings 6, also grouted into suitable openings leading to the hollow space within the foundations 2. The condenser tubes 7 extend from one tube plate to the other, and may be supported by sagging plates 8 mounted on side supports 9, and a stay 10 may be provided secured to the tube plates and sagging plates. The cover plates 11 for the water heads of the condenser may be made of cast-iron, one of which is secured to the rings 6 at one end of the condenser, and the other being bolted to an annular part 12 which is bolted to the ring 6 at the other end of the condenser. The inlet and outlet for the circulating water are led into the water head at one end, this being divided by a horizontal partition 13, so that the water passes through the tubes in the one direction to the other end of the condenser and then returns back through the other portion of the tubes to the end at which it entered in the usual manner. The outlet for condensate is formed by a conduit 14 provided with a metal flange, to which the suction pipe from the condensate pump may be attached. Conduits 16 in the foundations provide an outlet through which air and non-condensable gases are extracted. 17 is a conduit through which the turbine may exhaust to the atmosphere when the condenser is out of service. A suitable amount of space is left around the condenser tubes at the sides to permit of a passage round the condenser both for steam and for inspection purposes, admission thereto being obtained through the exhaust steam opening at the top or through the conduit 17. (*Accepted December* 31, 1918.)

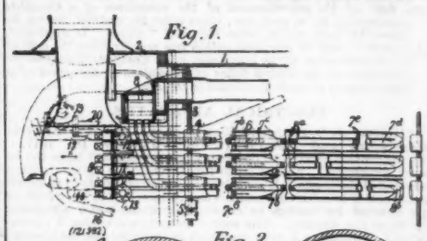
122,068. Swan, Hunter and Wigham Richardson, Limited, Walker, Newcastle-on-Tyne, and A. McClelland, Benton, Newcastle-on-Tyne. Steam Superheaters. (5 *Figs.*) February 27, 1918.—Steam superheaters as heretofore fitted to marine boilers have consisted of a number of superheater elements, each element having a plurality of U-loop pipes extending into a corresponding number of smoke or fire tubes of the boiler, the saturated steam inlet and superheated steam outlet ends of these elements being secured to one or both sides of a header arranged vertically in the uptake and comprising saturated and superheated steam chambers. According to this invention, the steam inlet and outlet ends of all the superheater elements appertaining to two or more rows of boiler smoke tubes, or to all the elements appertaining to one nest of the boiler smoke tubes, are expanded in holes in a common plate which is secured to the side or wall of the header by screw devices, openings or holes in the wall of the header communicating with the saturated steam chambers and superheated steam chambers of the header so that the saturated steam can enter the saturated steam inlet ends of the elements and the superheated steam can pass out of the superheated steam ends into the superheated steam chambers in the header, whence it passes to the engine. 1 (Fig. 1) is the tubeplate at the smoke-box end of the boiler, and 2 are the smoke tubes of the boiler. 3 are the superheater elements of the usual U-loop type, the U-pipes of which as usual extend into several smoke tubes in the same row, there being usually at least two

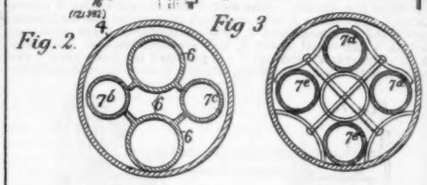




superheater elements to a row of smoke tubes. $3a$ and $3b$ are respectively the saturated steam inlet portions and the superheated steam outlet portions of the superheater elements secured to the side of the header 23 and leading respectively into a saturated steam chamber and into a superheated steam chamber of the header. The header 23 is of a known type, *i.e.*, having in its rear portion $3c$, adjacent the tubeplate 1, two longitudinal steam chambers or passages arranged side by side, one for receiving saturated steam from the boiler and the other for receiving superheated steam from the superheater elements and delivering the steam to the usual steam pipe or pipes leading to the engine cylinders, a series of steam chambers, one above the other, being arranged in front of the said two passages and separated from each other by transverse partitions or walls, and alternate steam chambers being for saturated and superheated steam respectively. According to the present invention, the ends $3a$ and $3b$ of all the elements appertaining to a nest of smoke tubes are expanded in a single plate 5 which, as shown, is secured to the side of the header by screw devices. Openings are formed in the sides of the header, at 13 and 14, the ends $3a$, $3b$, of the elements in the plates 5 registering with these openings which are covered by the plates 5, suitable thickened portions or flanges 8 being formed on the partitions to provide for making the necessary steamtight joint between the plates 5 and the said partitions; flanges 9 are also formed on the header to receive the screw devices and to make the necessary joint between the plates 5 and the headers. (*Accepted January* 22, 1919.)

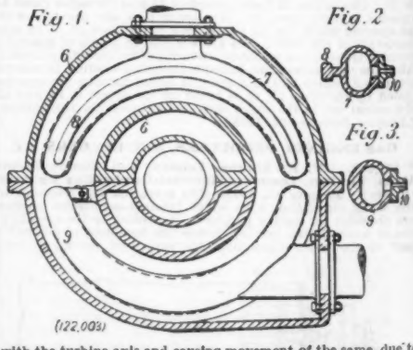
121,982. G. H. Willans, Gloucester, and E. S. Luard, Westminster, London. Feed-Water Heater and Steam Superheater. (4 *Figs.*) November 9, 1917.—This invention consists in a combined superheater and feed-water heater for locomotive and other fire-tube boilers. 1 indicates the barrel of the boiler, 2 the smoke-box, 3 the smoke-box tubeplate, and 4 the usual enlarged smoke tubes of the boiler into which the superheater elements extend. 5 are the usual relatively small smoke tubes of the boiler. 6 are the feed-water heater elements, there being, in the example shown, three of these elements, one extending into each of the boiler smoke tubes 4 containing a superheater element of the short return loop type. The saturated steam inlet and superheated steam outlet ends of the several superheater elements, are bent upwardly and secured to the bottom of the header 8 in the smoke-box 2. As clearly shown in Figs. 2 and 3, the longitudinal steam inflow and outflow pipes (forming continuations of the end portions) of the superheater element extending into a smoke tube 4, are, for a portion of their length, slightly greater than the total length of the feed-water heater element 6 within the smoke tube, bent or set outwardly so that these pipes are a relatively wide distance apart, and lie near the sides of the smoke tube 4. These pipes are marked $7b$, $7c$, in Figs. 1 and 2. The pipes of the feed-water heater element 6 are situated one above the other so that this element lies in the central vertical plane of the smoke tube 4 and between the pipes $7b$ and $7c$ of the superheater element. As shown in Fig. 1, the pipes, marked $7d$ and $7e$, of the short return loop portion of the superheater element, are so formed or arranged that they, and their return bends or torpedo ends $8b$, lie in parallel oblique planes in the smoke tube 4, as hereinbefore mentioned, and the return bend $8a$ at the opposite end lies in the central vertical plane of the smoke tube. As clearly shown in Fig. 1, the legs or pipes of the U-shaped feed-water heater elements extend well forward into the smoke-box so that the extremities of these pipes are well clear of the ends of the superheater elements in the smoke-box, and the said extremities of the feed-water heater pipes are fitted with removable screw plugs 9 which, when removed, give access to the interior of the feed-water heater pipes for cleaning purposes in a known manner. The feed-water heater elements in adjacent smoke tubes are





connected to each other by flanges on short tubular pieces 11 on the adjacent pipes, communication being thus formed between the elements in adjacent smoke tubes. Similarly tubular connections 12 and $12a$ are connected to the inlet leg or pipe of the feed-water heating element 6 in the lowermost smoke tube 4, and to the outlet leg or pipe of the element 6 in the uppermost smoke tube. To the flange of the connection 12 is connected the flanged pipe 14, to which the cold or relatively cold feed water is admitted through a combination clack-valve device, 16 being the pipe through which water from the lower part of the boiler passes, through the valve device and pipe 14, into the feed-water heater elements 6, for circulating purposes, when the feed pump or injector is not working. To the tubular connection $12a$, the pipe 17 is connected, this pipe being connected to the stop valve 19 and from the casing of this valve to a pipe 20 leads, through the smoke-box tubeplate 3, into the steam space of the boiler. (*Accepted January* 22, 1919.)

122,003. H. L. Guy, Manchester. Steam Turbines. (5 *Figs.*) January 4, 1918.—This invention relates to removable nozzle boxes for steam turbines. The present invention provides a nozzle-box so constructed that means for guiding movement of the nozzle-box, due to expansion, may, if desired, be dispensed with. This is accomplished, according to the present invention, by providing the nozzle-box with a stiffening rib or ribs, or by increasing the thickness of its walls at parts so located that the box, when in position within the turbine wall, will have greater flexibility in a plane perpendicular to the turbine axis than in a plane parallel thereto. The turbine cylinder 6 has in the upper half a nozzle-box 7 provided with alongitudinal rib 8 (see Fig. 2) having the effect of stiffening the box in a direction parallel



with the turbine axis and causing movement of the same, due to expansion, to take place in a plane perpendicular to said axis, the position which the box will assume when expanded being indicated in dotted lines. The nozzle-box 9 located in the lower half of the cylinder, has its outer wall, *i.e.*, the wall opposite the nozzle openings 10 increased in thickness as shown in Fig. 3, which will cause movements of the box, due to expansion, to take place in a plane perpendicular to the turbine axis as indicated by the dotted lines. With nozzle boxes constructed as described above, although guiding means may be dispensed with, it may in some cases be found desirable to provide suitable restraining means for preventing movement of the nozzle-box in the axial direction of the turbine. (*Accepted January* 22, 1919.)

PURCHASE OF MACHINE TOOLS, FRANCE.—The *Journal Officiel* of January 21 publishes a decree revoking the provisions of the decree of August 1, 1918, which controlled the trade in machine tools and mechanical appliances. Consequently purchases abroad which have been centralised by the "Comptoir d'Achat des Machines-outils," Paris, may now be effected by private parties or firms, subject to the granting of an import licence by the French Inter-Departmental Commission on Metals and Munitions of War. Article 2 of the decree provides that the "Comptoir d'Achats des Machines-outils" will complete the operations now in hand.